Appendix L – Part II. Exhibits of the James Irrigation District Comment Letter on the Draft Mendota Pool Group 20-Year Exchange Program EIS/EIR, Dated January 14, 2019

Appendix L – Exhibit 16 of the James Irrigation District Comment Letter

MONTHLY AND ANNUAL AVERAGE WATER QUALITY (TDS)

DELTA MENDOTA CANAL - CHECK 21

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1999	NR	NR	NR	NR	NR	NR	NR	199	285	315	353	282	299
2000	389	366	317	280	294	255	237	214	242	315	338	405	304
2001	465	409	394	377	314	284	233	322	409	383	368	393	362
2002	403	378	398	331	300	277	213	297	371	384	364	412	344
2003	399	358	376	312	308	194	162	205	235	328	352	362	299
2004	356	353	349	300	300	279	234	243	304	344	346	472	323
2005	397	376	302	291	333	172	207	234	263	239	332	347	291
2006	331	314	314	377	437	340	207	214	208	202	243	326	293
2007	396	384	339	310	293	302	188	236	296	324	341	372	315
2008	451	381	413	358	348	358	264	332	390	325	316	506	370
2009	575	560	448	377	363	373	215	303	357	353	324	390	385
2010	507	457	439	452	309	213	184	227	308	323	343	353	342
2011	442	268	254	330	291	232	187	206	190	202	223	304	261
2012	426	442	574	497	347	271	219	248	277	364	388	420	373
2013	414	386	406	441	330	334	249	330	396	372	433	489	382
2014	535	525	531	470	389	433	466	479	531	447	465	534	***484***
2015	***609***	550	496	558	491	437	440	502	493	465	498	532	***506***
2016	572	480	391	446	356	315	252	242	348	398	318	NR	374
2017	NR	NR	88	76	88	69	97	125	129	151	179	242	126
2018	341	329	362	212	187	218	184	214	319	338	335	393	286

NOTES:

A VALUE OF "NR" INDICATES THAT NO READINGS ARE AVAILABLE FOR THE TIME PERIOD.

ALL VALUES REPORTED AS PPM OR MILLIGRAMS PER LITER AND CALCULATED ASSUMING TDS = 0.64 * EC.

CONTRACT STANDARD IS MONTHLY AVERAGE NO GREATER THAN 600 PPM AND ANNUAL AVERAGE NO GREATER THAN 450 PPM.

VALUES EXCEEDING STANDARDS ARE IN BOLD AND SHADED.

Appendix L – Exhibit 17 of the James Irrigation District Comment Letter

MONTHLY AND ANNUAL AVERAGE WATER QUALITY (TDS)

JAMES IRRIGATION DISTRICT P-BOOSTER STATION

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
2007	NR	NR	NR	NR	NR	519	409	489	576	***639***	***680***	***667***	***568***
2008	***754***	***613***	511	522	***697***	554	506	575	***612***	NR	NR	NR	***596***
2009	NR	NR	***686***	***745***	***916***	555	454	580	***646***	***604***	***624***	***633***	***641***
2010	***789***	***615***	548	***694***	***750***	268	273	323	376	354	383	237	***467***
2011	49	190	268	33	32	23	75	201	190	223	206	NR	133
2012	NR	NR	NR	NR	NR	NR	NR	NR	NR	596	***666***	583	***623***
2013	383	437	587	***710***	***674***	582	549	***614***	NR	NR	NR	NR	***558***
2014	NR	***645***	***733***	***718***	***941***	***810***	***652***	***791***	***912***	***907***	***859***	565	***784***
2015	584	***790***	***734***	***682***	***894***	***923***	***815***	***894***	***967***	***917***	***858***	***729***	***816***
2016	***789***	***779***	***697***	***638***	***912***	***681***	547	576	***623***	***757***	***741***	553	***693***
2017	391	54	43	40	28	23	49	130	131	173	233	250	127
2018	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

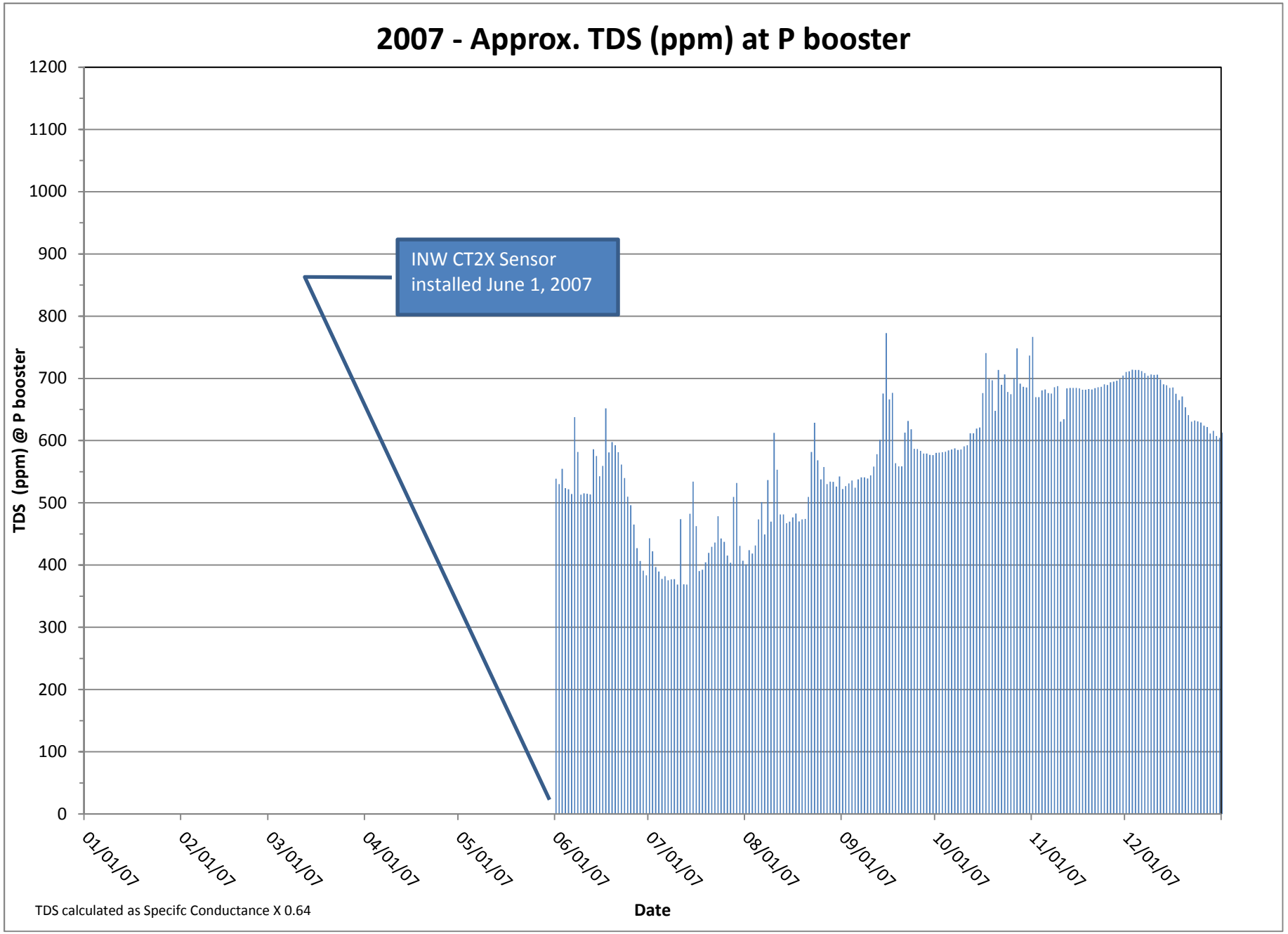
NOTES:

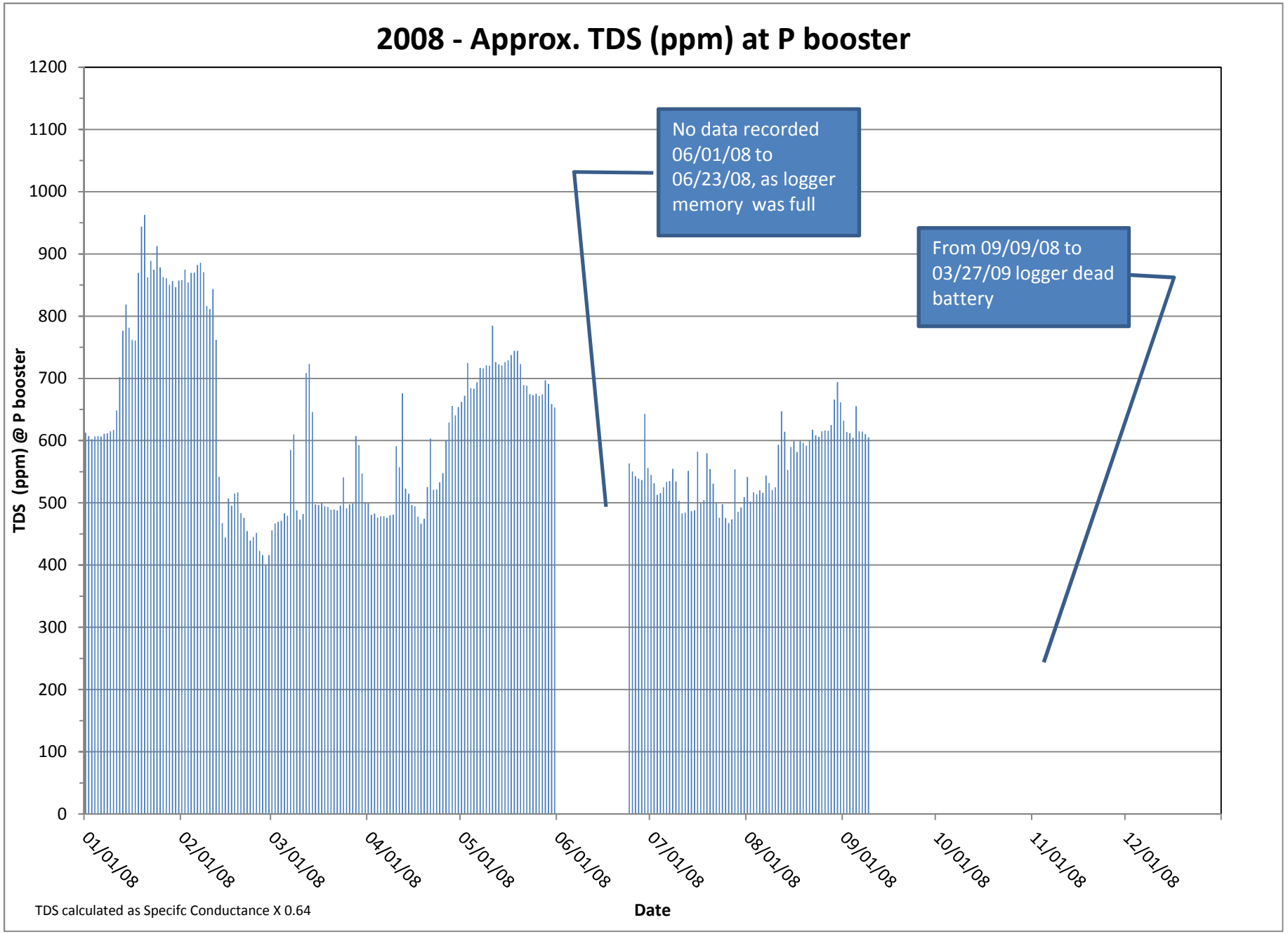
A VALUE OF "NR" INDICATES THAT NO READINGS ARE AVAILABLE FOR THE TIME PERIOD.

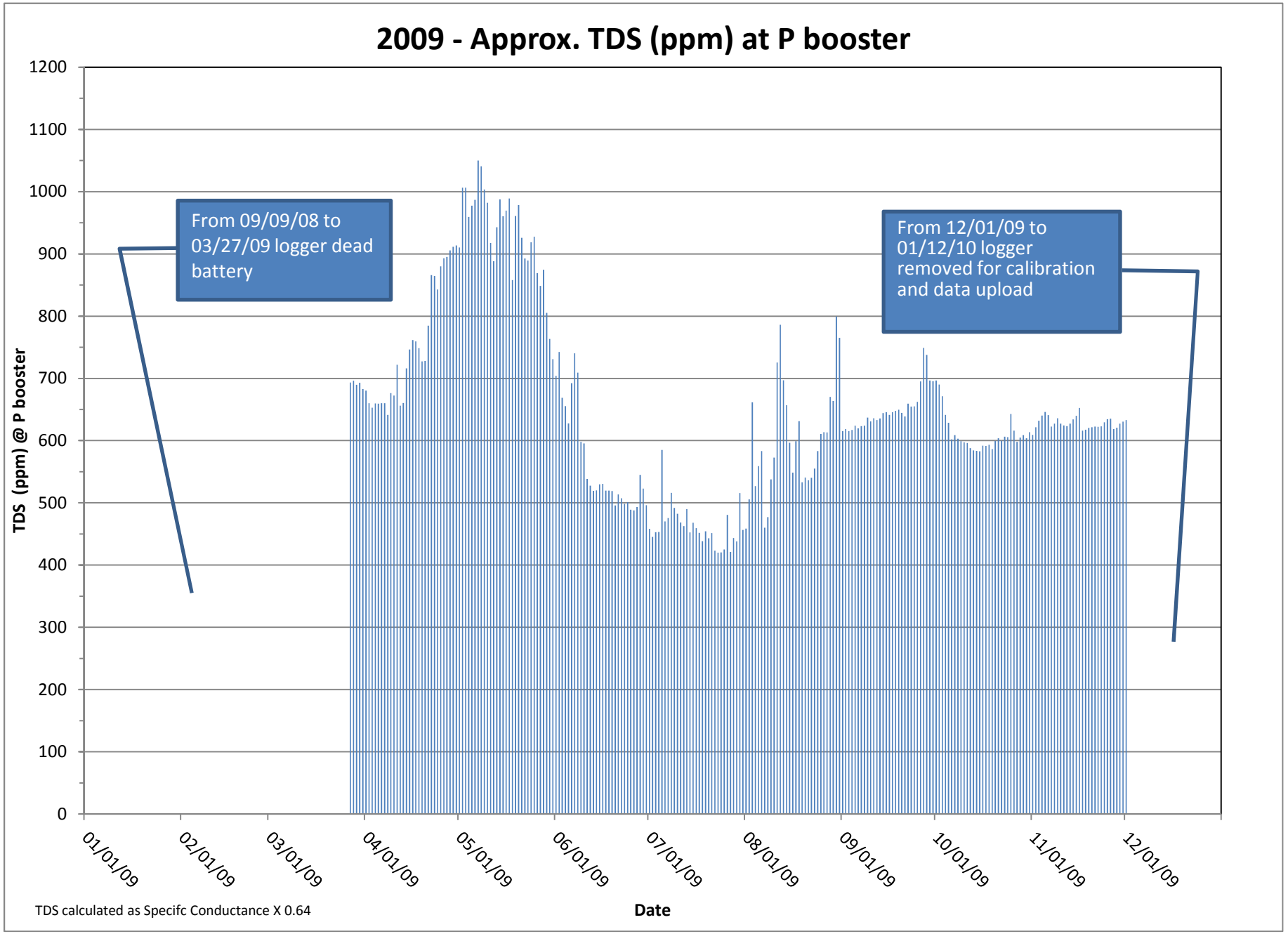
ALL VALUES REPORTED AS PPM OR MILLIGRAMS PER LITER AND CALCULATED ASSUMING TDS = 0.64 * EC.

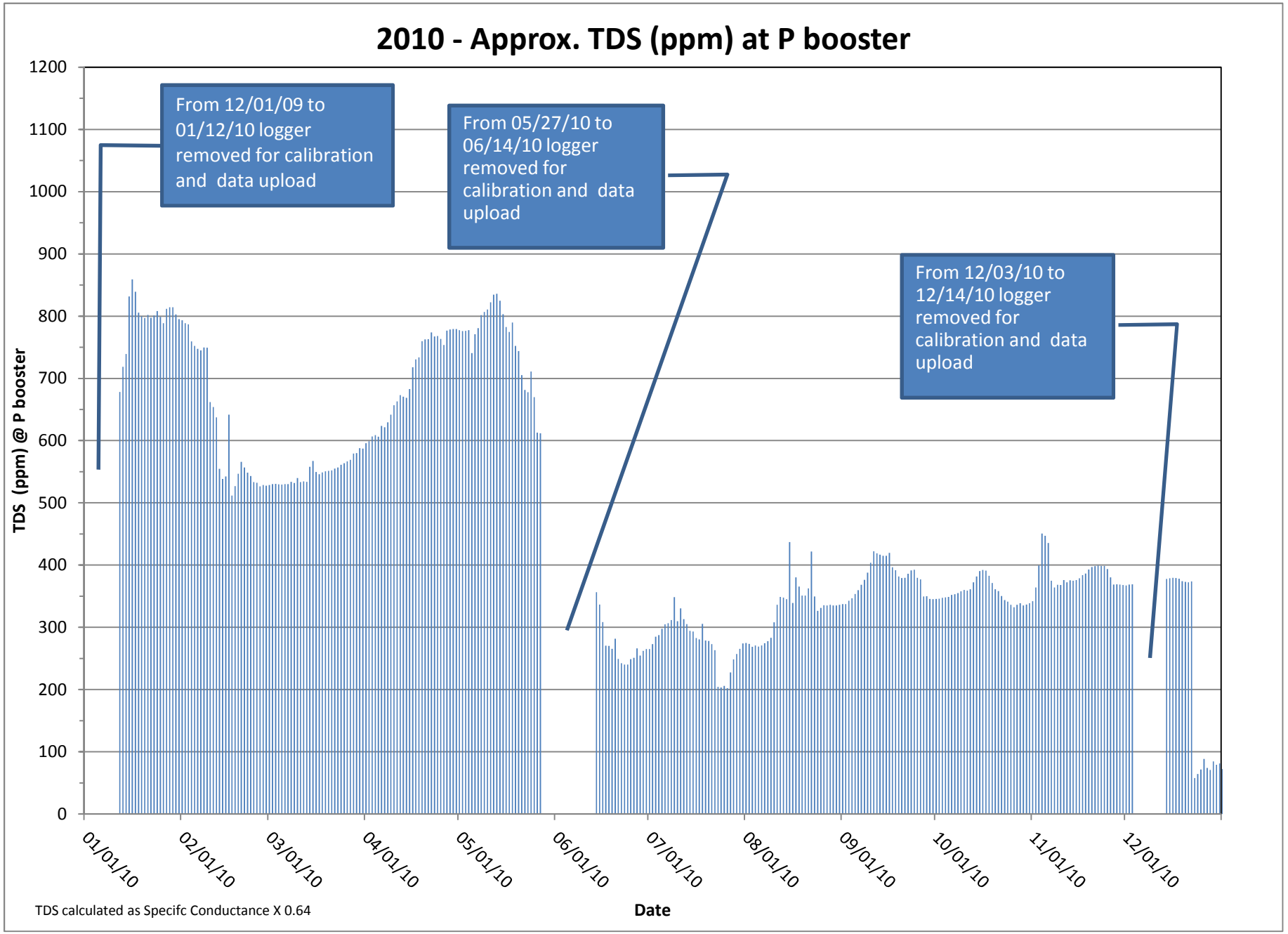
CONTRACT STANDARD IS MONTHLY AVERAGE NO GREATER THAN 600 PPM AND ANNUAL AVERAGE NO GREATER THAN 450 PPM.

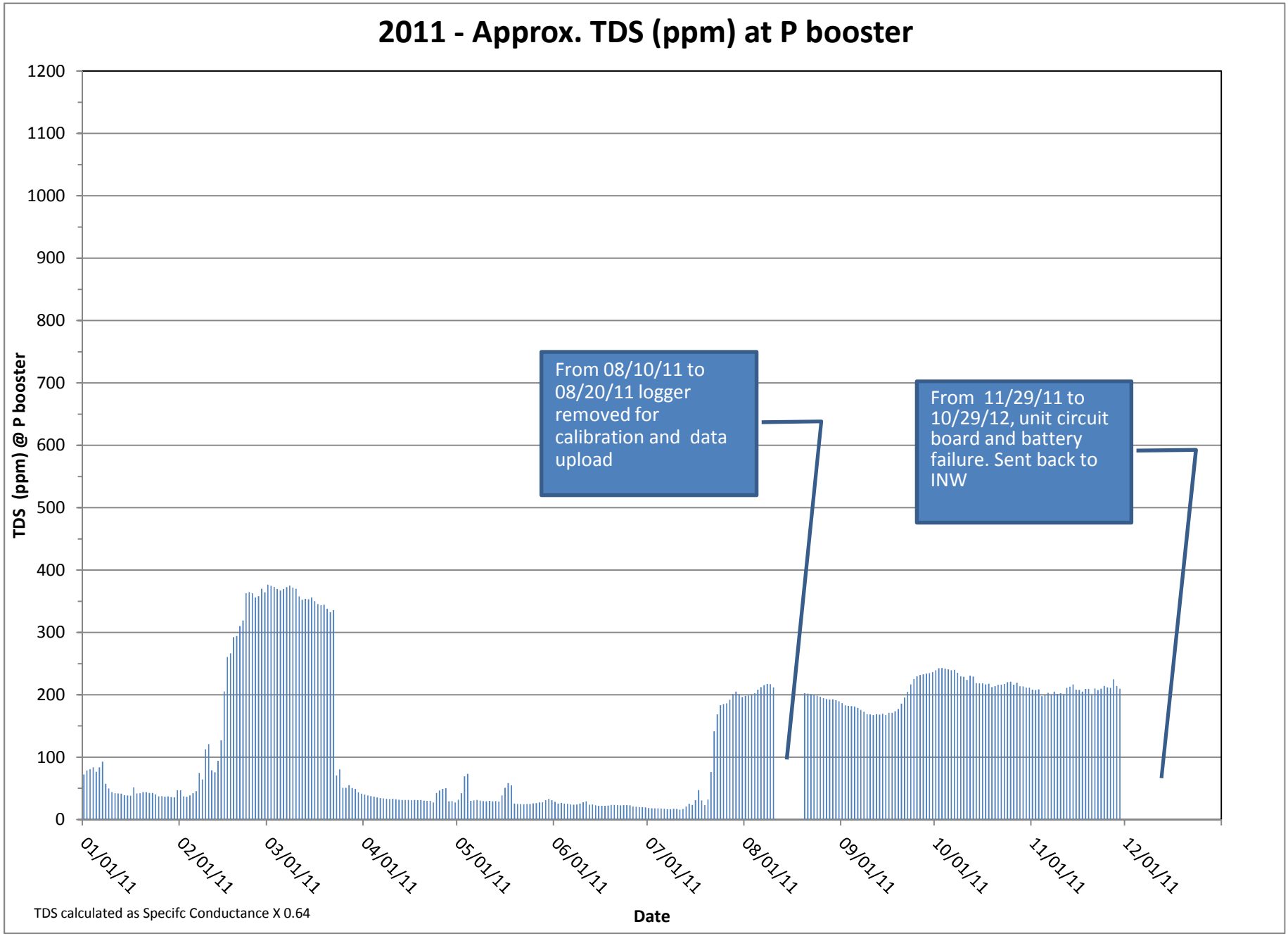
VALUES EXCEEDING STANDARDS ARE IN BOLD AND SHADED.

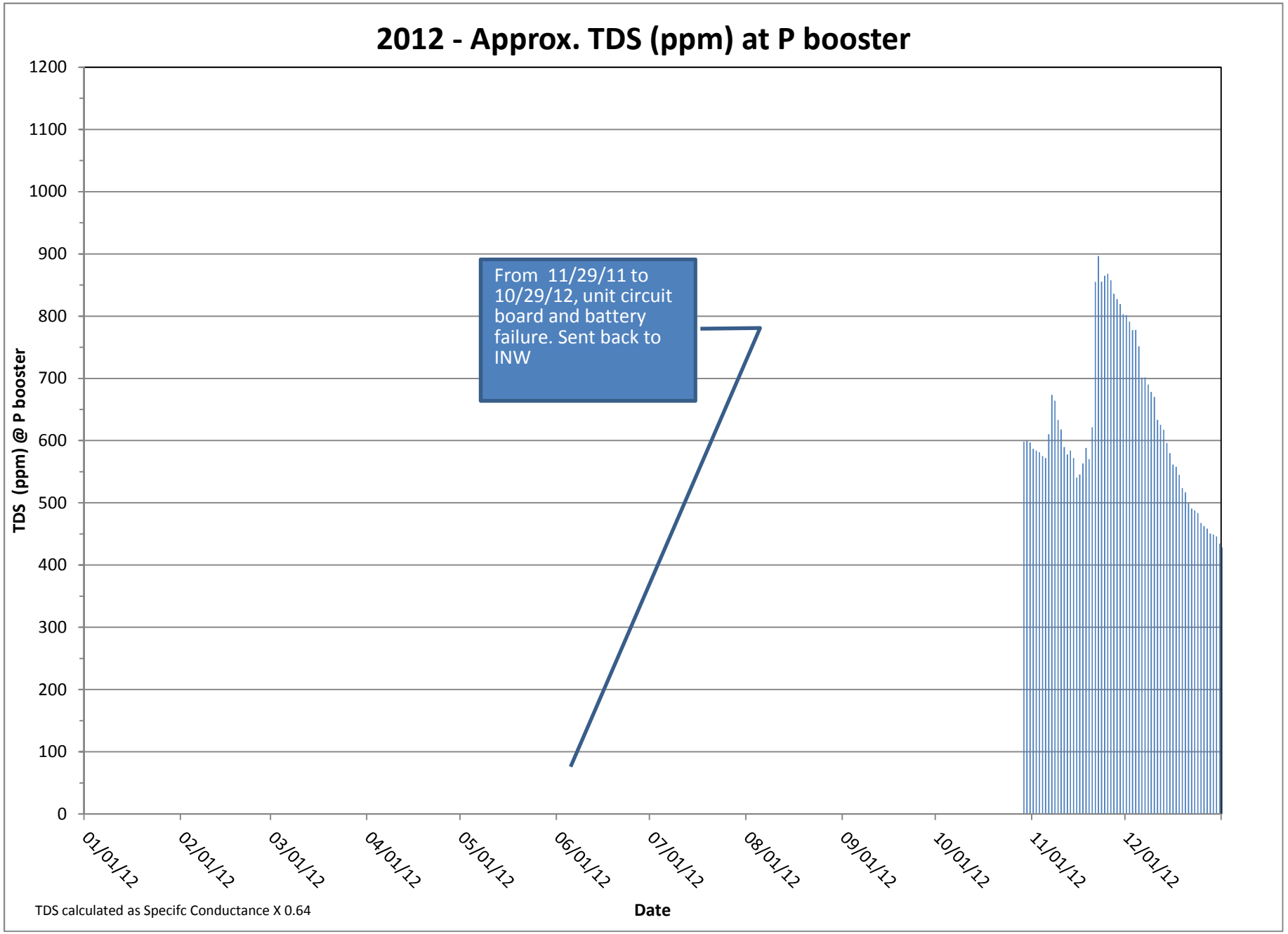

2007 - Approx. TDS (ppm) at P booster
INW CT2X Sensor
installed June 1, 2007
TDS (ppm) @ P booster
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
01/01/07
02/01/07
03/01/07
04/01/07
05/01/07
06/01/07
07/01/07
08/01/07
09/01/07
10/01/07
11/01/07
12/01/07
Date
TDS calculated as Specifc Conductance X 0.64

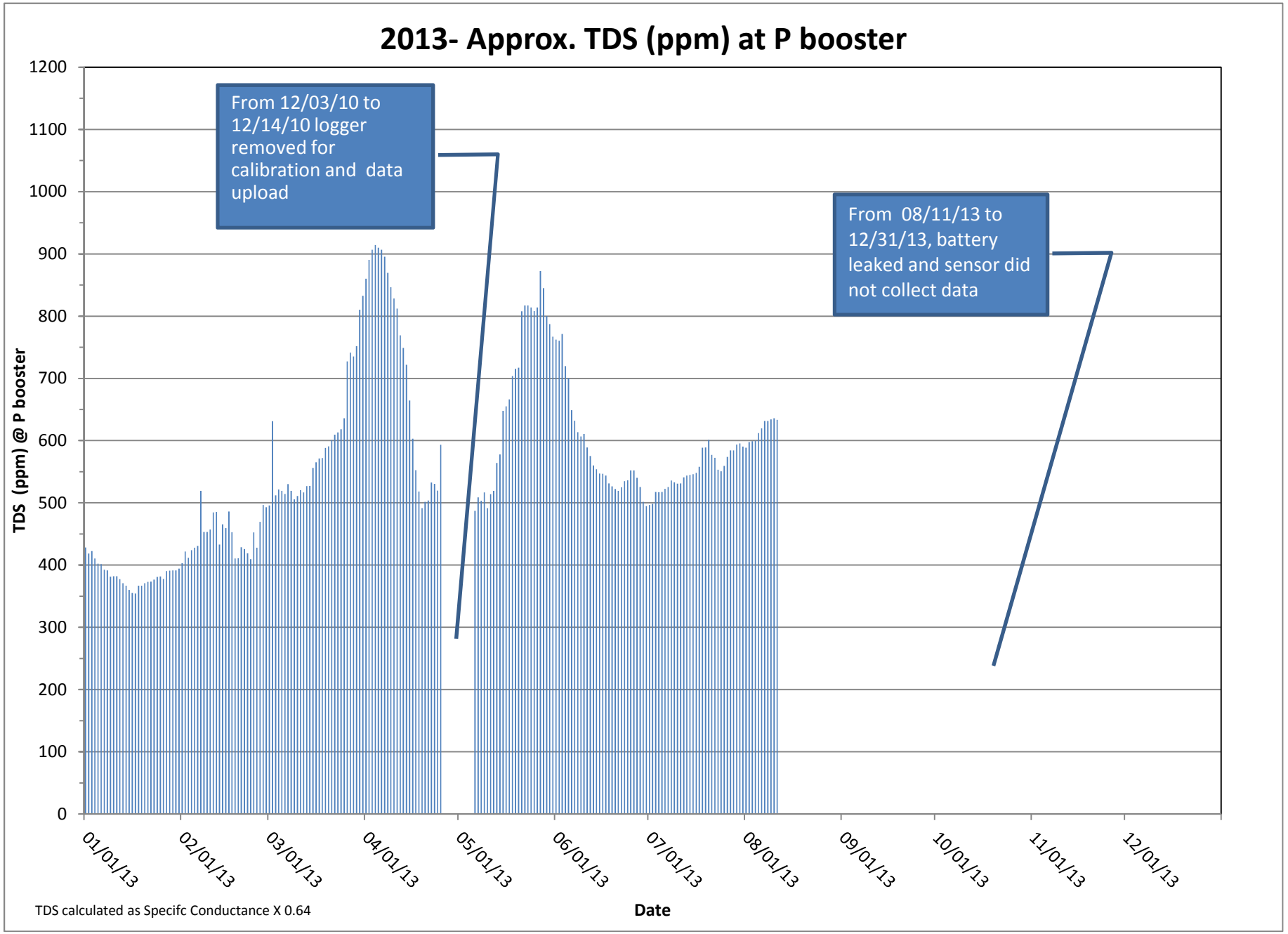

2008 - Approx. TDS (ppm) at P booster
TDS (ppm) @ P booster
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
No data recorded 06/01/08 to 06/23/08, as logger memory was full
From 09/09/08 to 03/27/09 logger dead battery
01/01/08
02/01/08
03/01/08
04/01/08
05/01/08
06/01/08
07/01/08
08/01/08
09/01/08
10/01/08
11/01/08
12/01/08
Date
TDS calculated as Specifc Conductance X 0.64

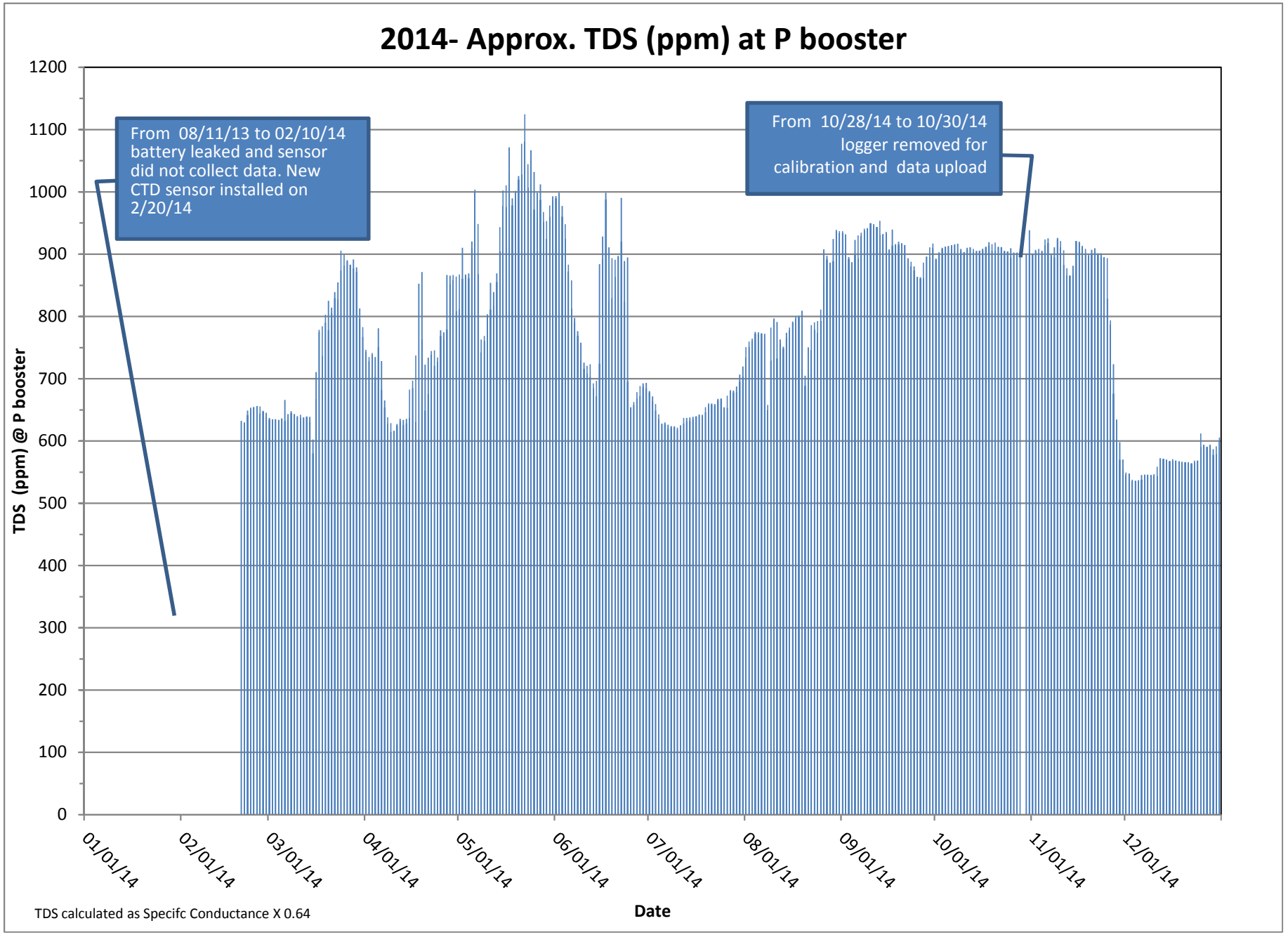

2009 - Approx. TDS (ppm) at P booster
From 09/09/08 to 03/27/09 logger dead battery
From 12/01/09 to 01/12/10 logger removed for calibration and data upload
TDS (ppm) @ P booster
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
01/01/09
02/01/09
03/01/09
04/01/09
05/01/09
06/01/09
07/01/09
08/01/09
09/01/09
10/01/09
11/01/09
12/01/09
Date
TDS calculated as Specifc Conductance X 0.64

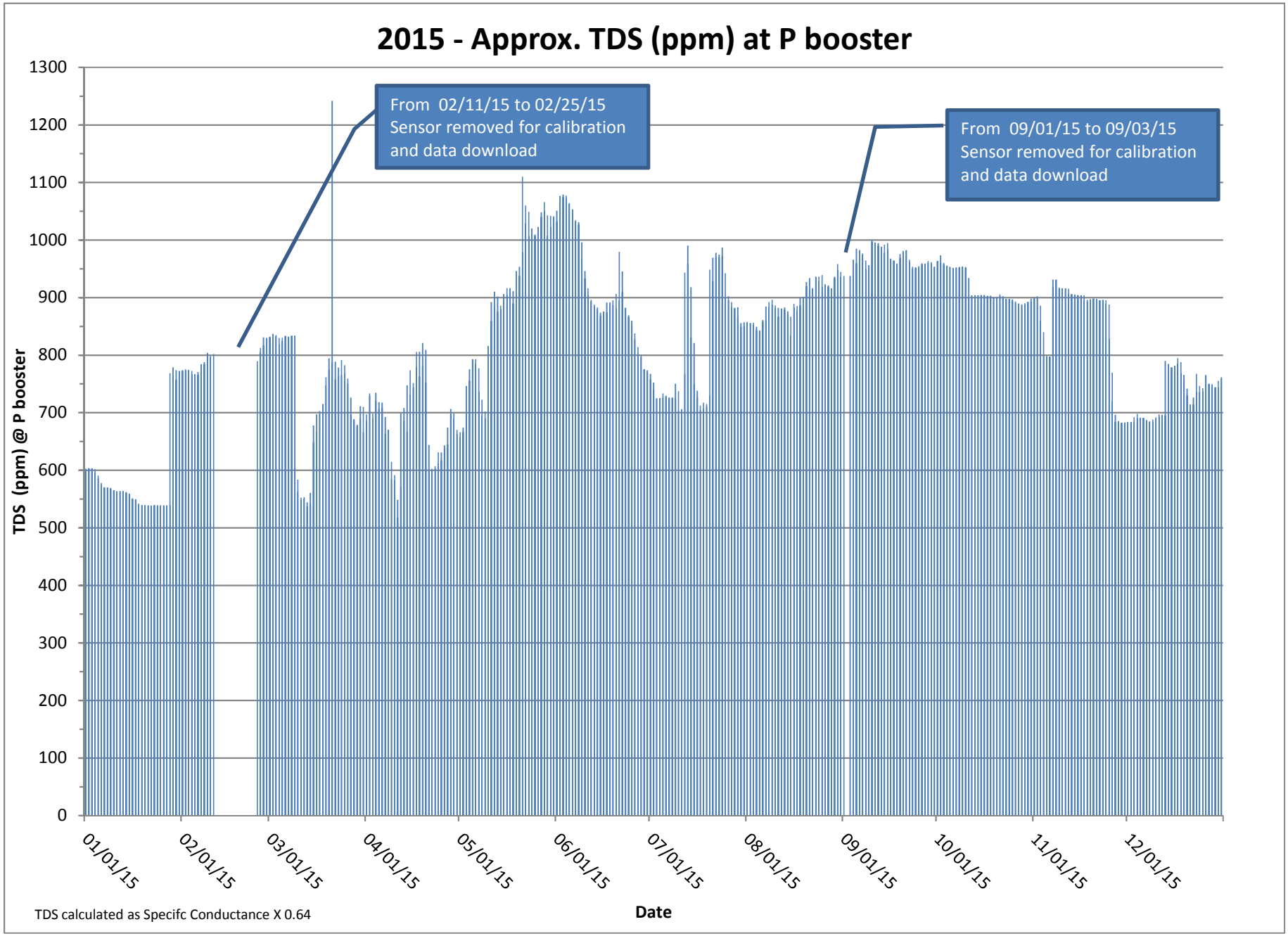

2010 - Approx. TDS (ppm) at P booster
From 12/01/09 to 01/12/10 logger removed for calibration and data upload
From 05/27/10 to 06/14/10 logger removed for calibration and data upload
From 12/03/10 to 12/14/10 logger removed for calibration and data upload
TDS (ppm) @ P booster
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
01/01/10
02/01/10
03/01/10
04/01/10
05/01/10
06/01/10
07/01/10
08/01/10
09/01/10
10/01/10
11/01/10
12/01/10
Date
TDS calculated as Specifc Conductance X 0.64

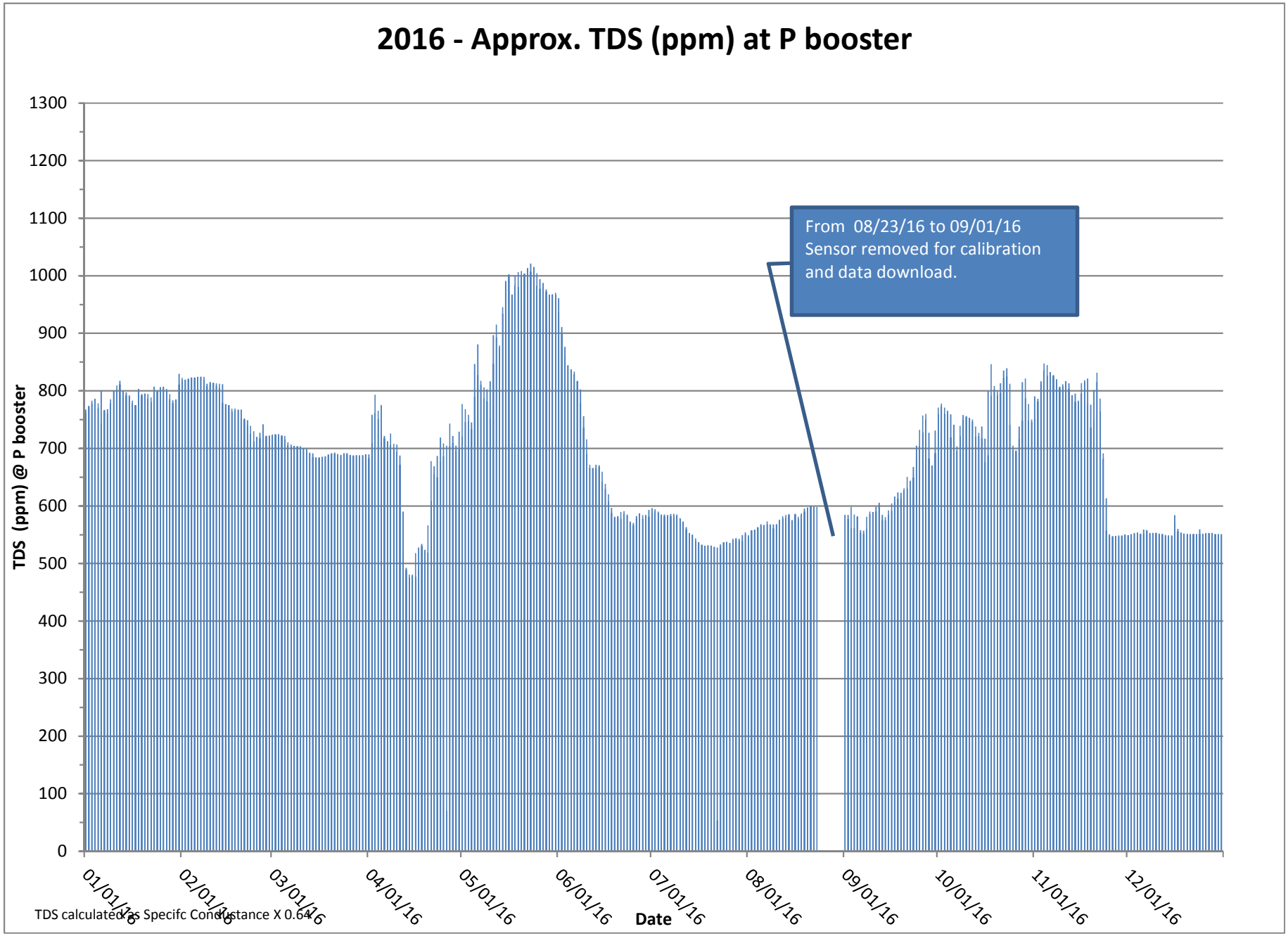

2011 - Approx. TDS (ppm) at P booster
TDS (ppm) @ P booster
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
From 08/10/11 to 08/20/11 logger removed for calibration and data upload
From 11/29/11 to 10/29/12, unit circuit board and battery failure. Sent back to INW
01/01/11
02/01/11
03/01/11
04/01/11
05/01/11
06/01/11
07/01/11
08/01/11
09/01/11
10/01/11
11/01/11
12/01/11
Date
TDS calculated as Specifc Conductance X 0.64

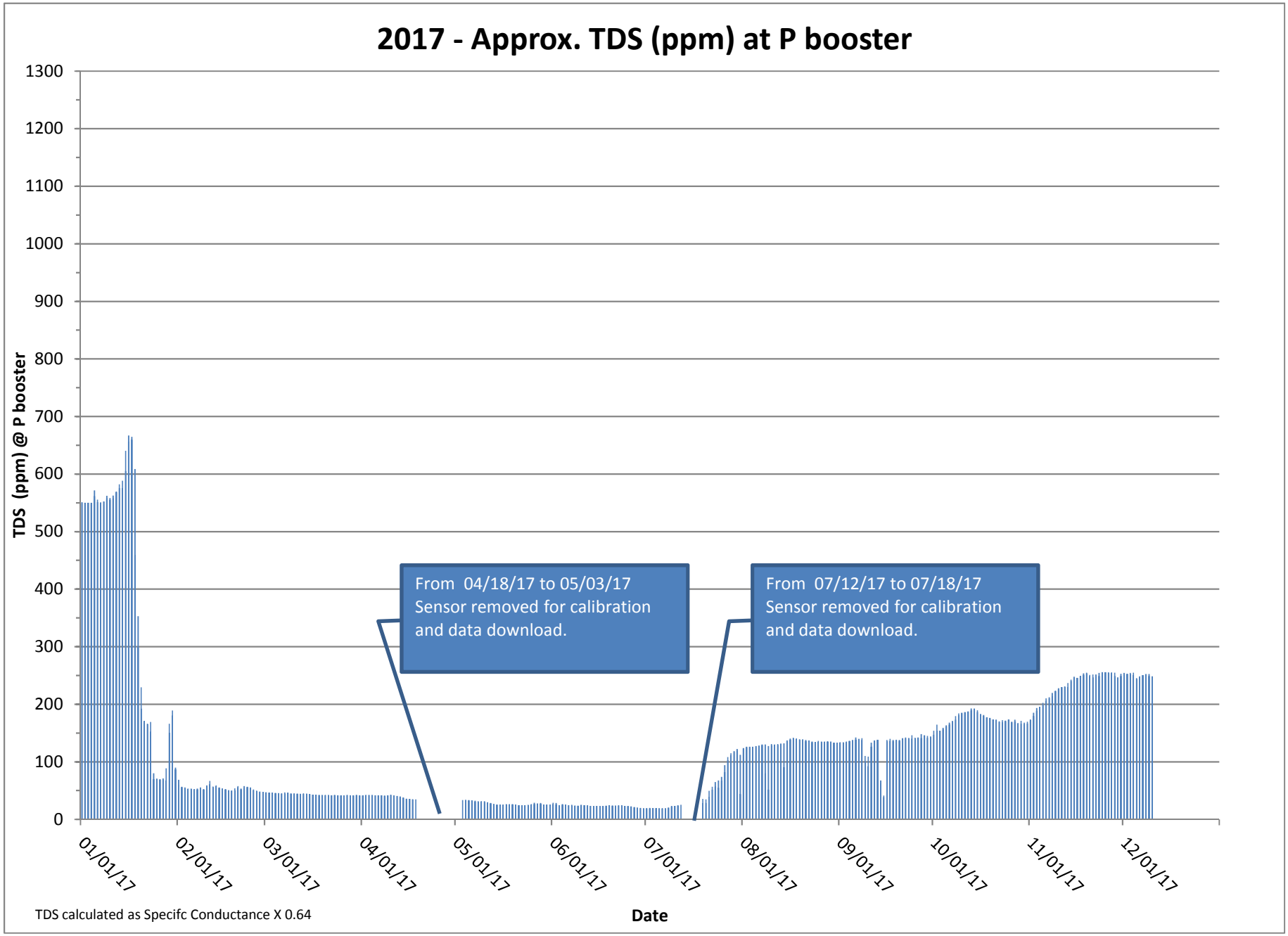

2012 - Approx. TDS (ppm) at P booster
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
TDS (ppm) @ P booster
From 11/29/11 to 10/29/12, unit circuit board and battery failure. Sent back to INW
01/01/12
02/01/12
03/01/12
04/01/12
05/01/12
06/01/12
07/01/12
08/01/12
09/01/12
10/01/12
11/01/12
12/01/12
Date
TDS calculated as Specifc Conductance X 0.64

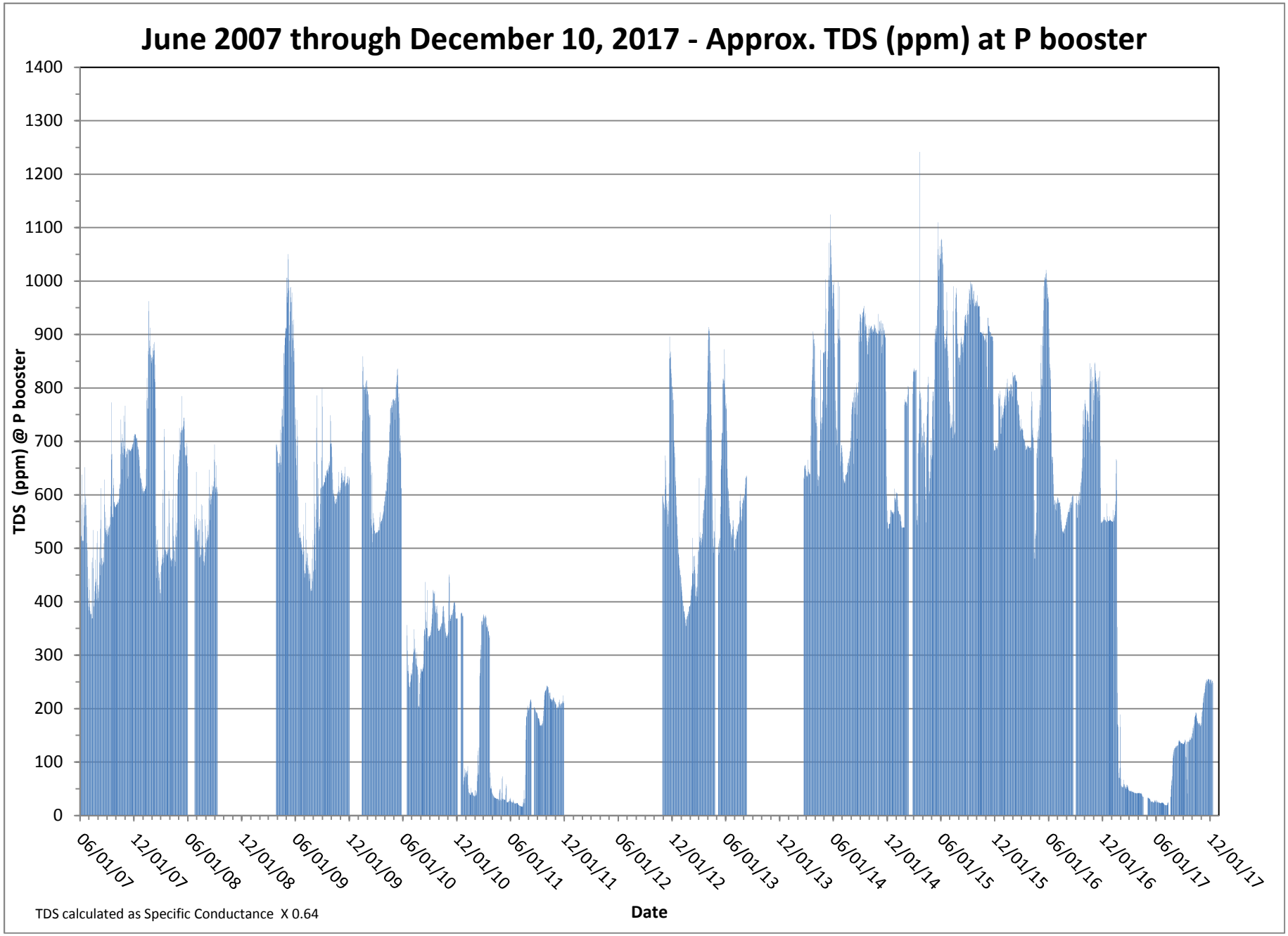

2013- Approx. TDS (ppm) at P booster
From 12/03/10 to 12/14/10 logger removed for calibration and data upload
From 08/11/13 to 12/31/13, battery leaked and sensor did not collect data
TDS (ppm) @ P booster
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
01/01/13
02/01/13
03/01/13
04/01/13
05/01/13
06/01/13
07/01/13
08/01/13
09/01/13
10/01/13
11/01/13
12/01/13
Date
TDS calculated as Specifc Conductance X 0.64


2014- Approx. TDS (ppm) at P booster
From 08/11/13 to 02/10/14 battery leaked and sensor did not collect data. New CTD sensor installed on 2/20/14
From 10/28/14 to 10/30/14 logger removed for calibration and data upload
TDS (ppm) @ P booster
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
01/01/14
02/01/14
03/01/14
04/01/14
05/01/14
06/01/14
07/01/14
08/01/14
09/01/14
10/01/14
11/01/14
12/01/14
Date
TDS calculated as Specifc Conductance X 0.64


2015 - Approx. TDS (ppm) at P booster
From 02/11/15 to 02/25/15
Sensor removed for calibration
and data download
From 09/01/15 to 09/03/15
Sensor removed for calibration
and data download
TDS (ppm) @ P booster
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
01/01/15
02/01/15
03/01/15
04/01/15
05/01/15
06/01/15
07/01/15
08/01/15
09/01/15
10/01/15
11/01/15
12/01/15
Date
TDS calculated as Specifc Conductance X 0.64


2016 - Approx. TDS (ppm) at P booster
TDS (ppm) @ P booster
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
From 08/23/16 to 09/01/16
Sensor removed for calibration
and data download.
01/01/16
02/01/16
03/01/16
04/01/16
05/01/16
06/01/16
07/01/16
08/01/16
09/01/16
10/01/16
11/01/16
12/01/16
Date
TDS calculated as Specifc Conductance X 0.64


2017 - Approx. TDS (ppm) at P booster
TDS (ppm) @ P booster
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
From 04/18/17 to 05/03/17
Sensor removed for calibration
and data download.
From 07/12/17 to 07/18/17
Sensor removed for calibration
and data download.
01/01/17
02/01/17
03/01/17
04/01/17
05/01/17
06/01/17
07/01/17
08/01/17
09/01/17
10/01/17
11/01/17
12/01/17
TDS calculated as Specifc Conductance X 0.64
Date


June 2007 through December 10, 2017 - Approx. TDS (ppm) at P booster
TDS (ppm) @ P booster
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
06/01/07
12/01/07
06/01/08
12/01/08
06/01/09
12/01/09
06/01/10
12/01/10
06/01/11
12/01/11
06/01/12
12/01/12
06/01/13
12/01/13
06/01/14
12/01/14
06/01/15
12/01/15
06/01/16
12/01/16
06/01/17
12/01/17
Date
TDS calculated as Specific Conductance X 0.64

Appendix L – Exhibit 18 of the James Irrigation District Comment Letter

EST. 1968
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Technical Memorandum

To:	Steven Stadler, P.E., General Manager, James Irrigation District
From:	Michael Day, P.E., Principal Engineer, Provost & Pritchard Consulting Group, Inc. Eric Abrahamsen, P.E., Project Manager, Provost & Pritchard Consulting Group, Inc.
Subject:	Mendota Pool Group 20-Year Exchange Program Draft Environmental Impact Statement/Environmental Impact Report (EIS/EIR) State Clearinghouse # 2013041028 Joint Document of U.S. Department of the Interior Bureau of Reclamation and Westlands Water District November 2018 Include attachments at the end of this document
Date:	January 11, 2019

Introduction:

The water quality James Irrigation District (JID or James ID) receives from the Mendota Pool has taken a decided turn for the worse in the twenty years since the Mendota Pool Group Pumpers (MPG) began pumping well water into the Mendota Pool and exchanging it for high-quality Delta-Mendota Canal (DMC) surface water delivered to their properties in Westlands Water District (WWD), as facilitated by the United States Bureau of Reclamation (Reclamation or USBR). The environmental impacts of implementing a similar exchange program for another twenty years (Project) have been partially studied by MPG, WWD, and Reclamation in the subject draft EIS/EIR. Surprisingly, the EIS/EIR concludes that no significant environmental impacts would occur as a result of the Project in spite of ample evidence to the contrary in the documents themselves. Furthermore, the document is deficient for its failure to analyze the impacts to JID, despite the fact that JID is likely to suffer more than others from the water quality impacts of the Project.

The following is a technical review of subject draft EIS/EIR. Our resumes are attached hereto in **Attachment A - Resumes** to document our background and expertise to perform the review.

Background:

JID is located southeast of the Mendota Wildlife Area (MWA) and covers the area around the City of San Joaquin. JID provides irrigation water to (in 2018) 23,667 cropped acres. A large portion of JID's water supply is delivered through the Delta-Mendota Canal (DMC) under the terms of two contracts with Reclamation. The first is a settlement contract (Reclamation Contract No. 14-06-200-700-A, dated December 23, 1963) made with JID in settlement of its water rights on the Fresno Slough and San Joaquin River (SJR) that were impaired by the construction of Friant Dam on the SJR at Millerton Lake, under which Reclamation provides up to 9,700 AF of Schedule 2 water in normal years and 7,600 AF in dry years according to the schedule in Table 1.

Table 1 - USBR Scheduled Water Deliveries to JID for Schedule 2 Water (AF)

Hydrologic Year Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Normal	0	600	800	1,300	1,900	2,500	2,000	400	200	0	0	0
Dry	0	600	800	1,000	1,500	1,900	1,400	300	100	0	0	0

The second is a Central Valley Project water supply contract (Reclamation Contract No. 14-06-200-700A-LTR1, dated February 25, 2005 for up to 35,300 acre-feet of water each year. The water is generally delivered in the spring and summer months and varies each year based on demand, availability, and schedules set by the USBR. These water deliveries averaged 13,706 AF/year between 2005 and 2014, or only 39% of the contract amount.

Failure to Study JID:

The primary study area for the EIS/EIR exclude JID. As shown in figure 36 on page 184 of the EIS/EIR, it is notable that Mendota Pool continuous water quality check points are located only at the Exchange Contractor Canals and Mendota Wildlife Area (MWA), but not immediately downstream in the Fresno Slough at the JID P-Booster Plant. The EIS/EIR also does not contain any discussion of the impacts the Project will have, and is already having, on the water quality received by JID. It is also noticeable that the "program design constraints" are concerned with minimizing impacts on water quality for the Exchange Contractors, Wonderful Orchards, and the MWA, but not JID.

This exclusion of JID from the study area and failure to study impacts to James, and its soils, crops, and groundwater, is not justified. Study of impacts to MWA is insufficient to understand the impacts to James, which has different water uses, needs, and environmental resources at stake. In addition, JID is downstream from the MWA, and stopping the analysis at the MWA ignores two important realities. One is that there are many wells that discharge into the Pool between the MWA's intake and JID that also substantially degrade water quality. The other is that JID relies on blending higher-quality DMC water, delivered through the Mendota Pool, for dilution of its well water to protect crops.

The existing Project design constraints are flawed because they only constrain pumping on poor quality wells for exchange purposes when quality at Exchange Contractor canals and/or Mendota Pool exceed triggering thresholds, and only at certain times of the year that don't correlate to JID's irrigation season. And, pumping of poor-quality wells is allowed to continue for "local" Pool Pumper purposes (but not exchange to their lands in WWD) even when that degrades water delivered to MWA and JID.

Water Quality Impacts in JID:

The water quality section fails to properly address the poor quality (high in constituents of concern including SAR, Boron, and TDS) of the groundwater received by JID as a result of this project. The problem is confirmed by data collected by Provost & Prichard and by data contained in the EIS/EIR itself.

Provost & Prichard maintains and operates an Electrical Conductivity (EC) meter at the P-Booster plant. Daily readings from June 1, 2007 to June 19, 2018 were used to obtain approximate TDS readings by multiplying EC measurements in DS/m by 640. That data is graphed and attached hereto as **Attachment B – June 2007 through June 19, 2018 – Approx TDS (ppm) at P Booster**. The extremely high TDS readings in 2014 (a critically dry year) stand out, as seen below in Figure 1.

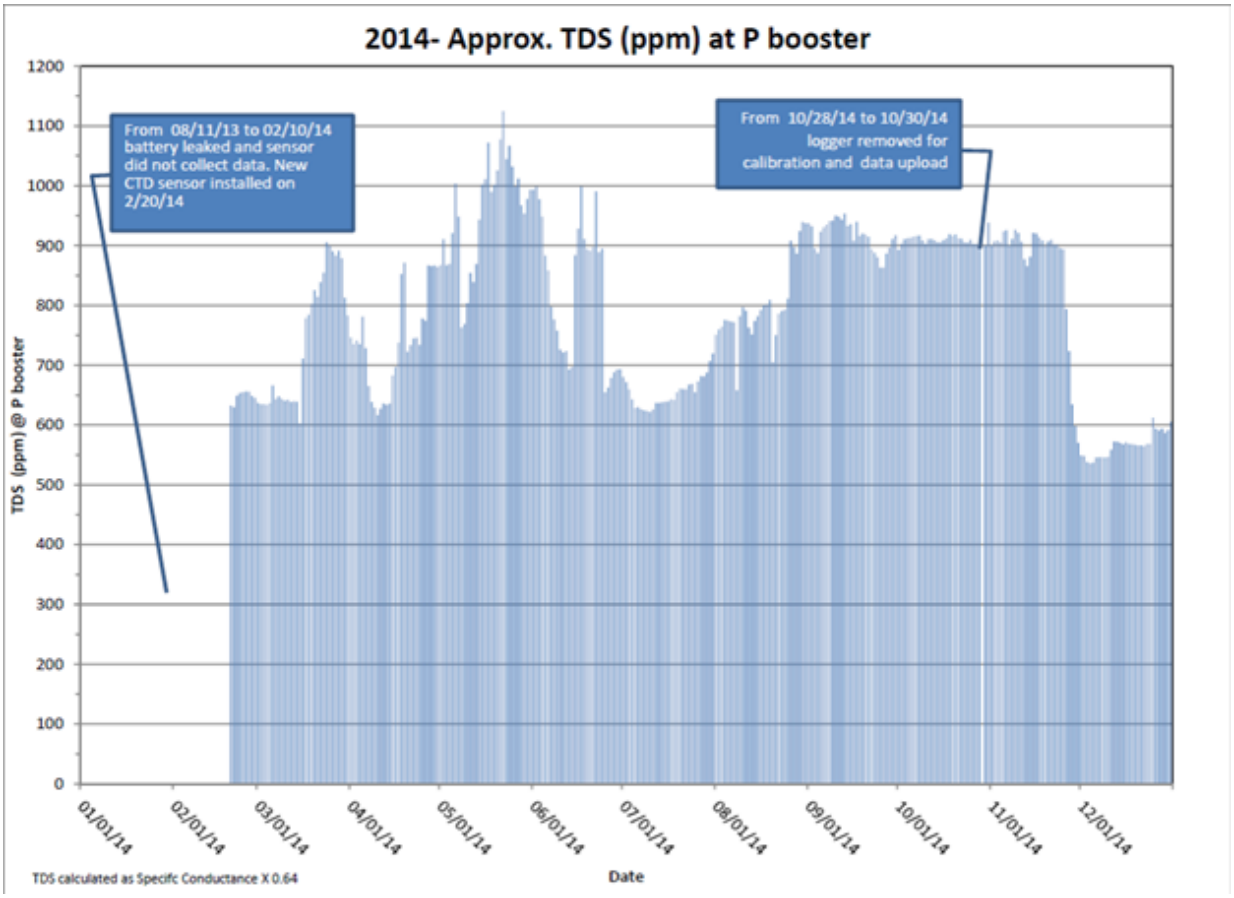

Figure 1 – Approximate TDS at P Booster (2014)

The severity of the problem in 2014 is also demonstrated in the EIS/EIR itself. Table 17 on page 183 includes data from grab sampling at the James P-Booster Plant reported in the 2014 Annual Report, Mendota Pool Group Pumping and Monitoring Program. Those samples had a median TDS of 992 mg/L and a maximum of 998 mg/L. Mendota Pool Group pump in water was a significant portion of the water put into the Pool and of the water received by JID in 2014 and other drought years that contributed greatly to cumulative impacts on JID from those pump ins.

Table 21 on page 189 of the EIS/EIR reveals that during 2014 the water received by JID was also very high in other constituents of concern, most importantly boron. The samples had a median boron concentration of 500 µg/L and up to 1150 µg/L.

As explained below, these high levels of degradation will have significant impacts in James.

Crop and Soil Impacts in JID:

Some of the crops grown throughout JID, and particularly in the northern area that receives mostly undiluted Mendota Pool Water, are very sensitive to salinity and Boron. **Figure 2** shows the distribution of the Crops in 2017 throughout JID. Also, many of the soils throughout JID, and particularly in the northern area, are vulnerable to sodicity problems (i.e. soil sealing and loss of permeability due to sodium imbalance, as indicated by elevated Sodium Adsorption Ratio (SAR).

In 2018, of JID's 23,667 cropped acres (see **Attachment C – District Crop Production Report Jan-Nov - 2018**), 12,038 were crops sensitive to salinity, boron, or both. Those crops include onions (2,187 acres), lettuce (67 acres), grapes (1,766 acres), almonds (7,867 acres), and walnuts (151 acres). Sweetcorn is also sometimes grown (James ID 2018 Operations Report – Page 6 – Crop Production DRAFT 01/02/09).

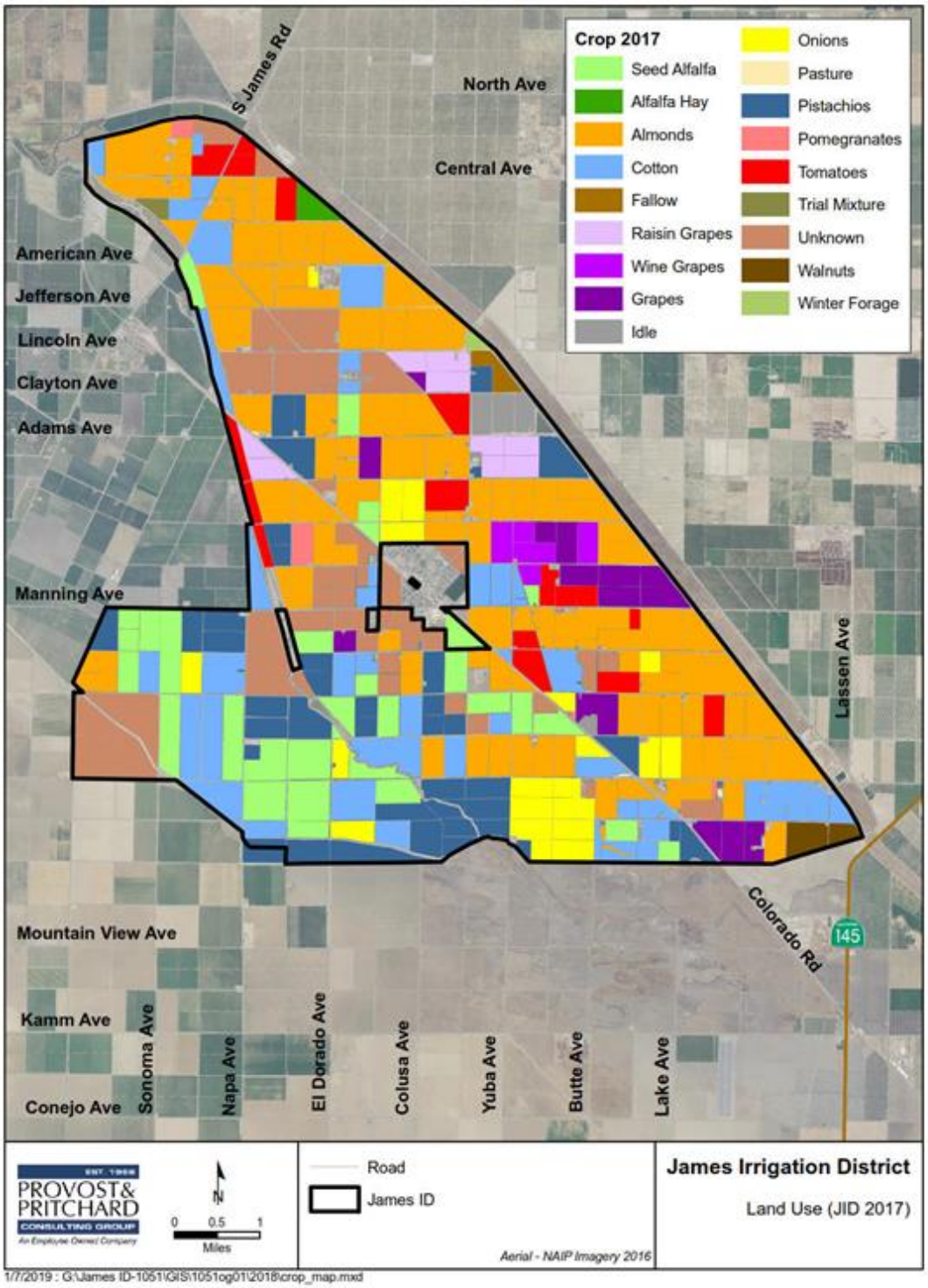

Figure 2: JID Crop Map

Many of these crops grown in JID suffer reduced yields at salinity levels far below 800 mg/L, including onions (512 mg/L), lettuce (576 mg/L), grapes and almonds (640 mg/L), and walnuts and sweetcorn (704 mg/L).[1] A yield reduction of 10% is expected for onions at 768 mg/L, lettuce and almonds at 896 mg/L, walnuts at 1,024 mg/L, and grapes and sweetcorn at 1,088 mg/L.[2] All of these thresholds were exceeded at some point in 2014, and according to data in the EIS/EIR itself the median TDS was 992 mg/L. That level exceeds the 10% yield reduction threshold for onions, lettuce, and almonds, which together make up over 42% of the cropped acreage in JID. By contrast, water in the DMC that year was measured at 481 mg/L, which does not exceed any of these thresholds. Furthermore, it is not clear how the annual averages in table 17 of the EIR were derived, and short-term concentrations may have been significantly higher, as evidenced by the data from Provost & Prichard's EC meter in Figure 1. Such averaging ignores the impacts of even brief periods of extreme concentrations, and the lack of transparency in how the averages are derived is detrimental to the understandability of the document.

Boron sensitivity for onions, grapes, and walnuts begins in the range of 0.5-0.75 mg/L (500-750 µg/L). The EIS/EIR does contain any analysis of the effects of the project on boron concentrations. Table 6-1 in Appendix D of EIS/EIR reports boron content from five grab samples at the JID booster plant with a minimum of 0.4 mg/L, a maximum of 1.5 mg/L, and median 0.5 mg/L. These levels, therefore, are at times sufficient to cause damage to boron sensitive crops, and boron is known to be much more difficult to leach out of crop root zones than salts are.

Problems with soil structure, infiltration, and permeability are strongly correlated with sodium imbalance (measured by high SAR).[3] The EIR/EIS does not discuss the projects impact on SARs or report SAR values that would allow a determination of the extent of the impact to JID. However, SAR data are reported for individual MPG pumper wells in Tables E1, E2, and E3 of Annual Reports Mendota Pool Group Pumping and Monitoring Program (attached hereto in **Attachment D – Appendices E1, E2, and E3 of 2016 Annual Report Mendota Pool Group Pumping and Monitoring Program**), and many are very high. SAR values from periodic grab samples at the JID booster plant are reported in Table G-1 of the 2016 Annual Report Mendota Pool Group Pumping and Monitoring Program (attached hereto in **Attachment E - Table G-1 of the 2016 Annual Report Mendota Pool Group Pumping and Monitoring Program**). Most of the values fall in the "increasing problems" range, and four are in the severe problems range.

Irrigation water with higher TDS and boron concentrations also requires more leaching water to avoid accumulating salts and boron in the root zone. It is possible to calculate the additional amount of water required to remove salts if TDS is known. But there are no guidelines for calculating leaching requirements for boron. However, even if water is available at a price JID's growers can afford (not likely in drought years) and applied properly, leaching moves the salts and boron into the groundwater,

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[1] Salinity, Boron, and SAR sensitivity numbers on this page based on R.S. Ayers and D.W. Westcott, *Water quality for agriculture*, Food and Agriculture Organization Irrigation and Drainage Paper 29 Rev. 1 (1994), attached hereto as **Attachment F**. TDS numbers are obtained using the formula: TDS = EC (DS/m) * 640. See also E.V. Maas and S.R. Grattan, *Crop Yields as Affected by Salinity*, in Agricultural Drainage Agronomy Monograph No. 38, American Society of Agronomy (R.W. Skaggs and J. van Schilfgaarde, Eds. 1999), attached hereto as **Attachment G**.

[2] These thresholds assume irrigation water for the entire season has these concentrations.

[3] See, e.g., Dennis Rolston, et al., *Effect of salt on soils*, California Agriculture (October 1984), pp. 11-13, attached hereto as **Attachment H**.

which presents problems for well water quality and future regulation under the Irrigated Lands Regulatory Program.

Other crop, soil problems, and irrigation system problems can occur due to high Chlorides, high PH, and water hardness that are also not disclosed, analyzed, or discussed in the Draft EIR/EIS. These problems can be associated with:

High Chlorides – toxic to some sensitive crops through root absorption after surface irrigation and crop leaves burn after sprinkler applications

High Nitrates – high levels can cause some crops to develop excessive vegetation instead of food or fiber production

Bicarbonate – overhead sprinkling of certain fruits and vegetable can leave "whitewash" on the skin of the produce that reduces its marketability

pH Imbalance – water outside the normal range of 6.5 – 8.4 can negatively impact plant physiological processes, soils and/or irrigation systems by dissolving or precipitating salts and through water hardness effects.

Manganese – can be toxic to some plants and/or feed slime-causing bacteria that can foul irrigation systems

Iron – concentrations greater than 5.0 mg/l may cause nutritional imbalances in certain crops and/or can feed slime-causing bacteria that can foul irrigation systems

Corrosivity or Erosivity – Certain combinations and concentrations of ions can increase the corrosion potential of water and soils in contact with metal or concrete components of irrigation distribution systems and on-farm irrigation systems.

Additional Salt Load to JID:

It is also important to understand that many tons of salt will come into JID as a result of the exchange Project that cause crop, soil, and groundwater problems, as noted above. The EIR/EIS does not account for this significant impact. As an example of how severe the problem is in dry years, consider the additional salt load to JID in May-September of 2014.

Table 2 (on the next page) shows the additional tons of salt brought into JID at the P-Booster Plant (above the amount that would have been brought in using DMC water if TDS was 450 mg/l) due to elevated salinity in those months.[4]

[4] To compute the total salt in an amount of water: Amount of Water (AF) * TDS (mg/l) * 1 gram/1000 mg * 1 pound/453.592 grams * 43,560 cubic feet /acre-feet * 28.317 litres/cu-ft * 1 ton/ 2000 pounds.

2014 Month	Volume (AF)	Approximate Monthly Average TDS (mg/l)	Maximum DMC TDS (mg/l)	Additional Salt level (mg/l)	Additional Tons Salt
May	739	941	450	491	493.4
Jun	3,799	810	450	360	1,859.6
July	1,278	652	450	202	351.0
August	256	791	450	341	118.7
September	128	912	450	462	80.4
Total					2,903.0

Table 2 – Increase in Salt in JID (2014)

Flawed Mixing Model:

The EIS/EIR relies on a flawed Mendota Pool mixing model that produces results inconsistent with actual readings in years for which the model was not validated. Mixing is done in two separate sections of the Pool independently, even though there is no physical barrier in the Pool at "Section AA" (see EIS/EIR Figure 6-1 in Appendix E part 1), and "complete mixing" is assumed on a monthly time step in each section. This means there are no factors for daily variation of activities, Pool water flow currents, wind-driven wave effects, dispersion, and advection as actually occur. The mixing model was not calibrated, rather it was "validated" but only using data from 2012, which followed an abundant water year (water year 2011) but was itself classified as dry. Therefore, supplies carried over in storage facilities from prior years delivered to and through the Pool made 2012 non-typical for dry conditions. It is particularly unjustified not to validate the model using data from water year 2014, the second half of a historic drought. The 2014 data presented in Table 17 of the EIS/EIR indicate a severe problem in dry years, which will be worse when cumulative projects and other future developments are considered, including climate change and the recently approved Bay Delta Water Quality Control Plan Update, that make future critical dry years like 2014 (and 2013) more likely. While the EIS/EIR does admit that concentrations of constituents of concern were high in 2014, it does not discuss Project constraints, mitigation, or alternatives that would avoid or substantially lessen those impacts to JID or realistically describe the impacts of the Project in future, similar years.

The baseline assumptions that feed the groundwater and mixing model are also not reasonable. It is assumed that MPG wells will pump approximately 33,395 AF/year into the Pool without the Project (No Project/No Action Alternative) for use on MPG owners' lands near the Pool (rather than in WWD), despite the fact that Figure 2 on page 4 shows that such adjacent uses account for a smaller share of pumping than the transfer pumping, between 5,000-15,000 AF/year. In an attempt to justify this assumption, the analysis assumes "reactivation of fallowed farmland" and "continuation of crop conversion trends," an unlikely combination of outcomes in light of the future implementation of the Sustainable Groundwater Management Act (SGMA). It also assumes an unreasonably high water demand of 5.1 AF/year per acre.

Averaging and Short-Term Impacts:

Tables 25 and 26 on pages 201-202 of the EIS/EIR predict no significant impact on TDS at MWA, but in light of the dry year data (from 2014) in Table 17 it is difficult to understand how this can be so. It

appears that some kind of averaging over the 20-year period is being employed, but the method is not clear even to an expert much less to the target audience of the document (decision-makers and the public). Furthermore, such averaging effectively ignores short-term changes in water quality that can have both short-term and medium-term impacts on crops and long-term impacts on soils, e.g., accumulation and loading of salts into James's soils and groundwater. Salts tend to increase in concentration (versus irrigation water concentration) and sometimes precipitate out as they move downward through the crop root zone and soluble salts travel out the bottom with leachate toward groundwater as crop evapotranspiration removes pure water from the root zone. For example, by simple mass balance, irrigating with 800 mg/l irrigation water with salts that don't precipitate in the soil and a ten percent leaching fraction can push leachate concentrations as high as 8,000 mg/l.

One year irrigating almonds, onions and other sensitive crops with water above thresholds for TDS, SAR, and boron is enough to cause yield and/or crop quality reductions and lasting soil permeability problems (without corresponding gypsum and leaching water to counteract the effects, both of which add more salts to the groundwater).

Conclusion:

Based on our review of the subject EIS/EIR, We believe it ignores critically important areas of analysis, particularly with respect to significant impacts to JID, rests on faulty assumptions, and does not present a complete and accurate picture of the environmental resource conditions at stake within JID's boundaries and the environmental impacts of the Project to JID, it growers, and their crops, soils and groundwater. JID will suffer significant impacts to its crops, soils, and groundwater that are not even discussed let alone analyzed.

ATTACHMENT A – Resumes

Mike Day, PE

Principal Engineer

Education

- ✓ B.S. Civil Engineering, California State University, Fresno

Registration/Certifications

- ✓ Civil Engineer, California #39494

Affiliations

- ✓ United States Committee on Irrigation & Drainage (USCID)

Areas of Expertise

- ✓ Water Resources Studies, Planning, Funding
- ✓ Irrigation Conveyance Design
- ✓ On-Farm Irrigation System Design
- ✓ Surface & Subsurface Drainage
- ✓ Groundwater Management
- ✓ Water and Groundwater Quality
- ✓ Energy

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Professional Summary

Mike Day is a principal project manager in water and energy resources engineering with over 35 years of experience. He has an extensive background in investigation, planning, and design of water and groundwater supply and storage facilities for local agencies and landowners. Mr. Day's areas of expertise include studies, planning, funding and financing through grants, loans, and Prop 218 elections, design, and construction management for water and groundwater distribution and storage facilities as well as surface and subsurface drainage facilities. He has expertise in water and groundwater quality and provides expert consultation for farms, water agencies, and energy utilities on a variety of energy-related topics.

Relevant Experience

Water Quality Exchange Study, Friant Water Users Authority, Southeastern San Joaquin Valley, California, Lead Researcher/Writer for Case Studies – Mr. Day led the research and writing team in the investigation of soil and groundwater impacts resulting in three water agencies (two agricultural and one urban) which have utilized State Water Project (California Aqueduct) water in-lieu of Central Valley Project-Friant Unit (San Joaquin River) water as a result of water transfer and exchange programs for over 30 years. A report was prepared to summarize observed water, soil and groundwater impacts, impacts to urban water treatment and distribution systems, agricultural water distribution and irrigation systems, and to estimate changes in applied salts through irrigation water quality and cultural (soil amendment) practices.

Irrigated Lands Regulatory Program Review and Monitoring, Various Water Agencies, Kern County, California, Project Manager – Mr. Day led Provost & Pritchard's initial monitoring of the Central Valley Regional Water Quality Control Board's Ag Waiver and Irrigated Lands Regulatory Program (ILRP) for Arvin-Edison Water Storage District; and through Young-Wooldridge on behalf of several agricultural water agencies in Kern County, provided engineering and hydro-geologic comments on the draft environmental impact report document for the ILRP. Mr. Day has also provided general oversight as Provost & Pritchard formed the Kern River Water Quality Coalition, staffed it, and provided advocacy, administrative, and technical work to assist its growers with ILRP compliance. This work included general oversight and quality assurance and control of the surface water monitoring program, Sediment Discharge Evaluation and Assessment Report and Groundwater Assessment Report.

Groundwater Evaluation, Tulare 144 Ranch, Tulare, California – Mr. Day analyzed quantity and quality of groundwater supply available to 1,800-acre farm in Tulare County, and projected the impact of increased future pumpage on groundwater levels and quantity.

Water Resources Evaluation, Maddox Farms Burrel Ranch, Helm, California – Mr. Day analyzed quantity and quality of surface water (from Kings River) and groundwater supply available to 5,000-acre farm in Fresno County.

CEQA Documentation, Berrenda Mesa Water District, Lost Hills, California, Project Manager – This project included the preparation of studies and documents for CEQA compliance for a reservoir spillway enlargement project, and also for a water transfer project.

Well and Pump Evaluation, Marchini Property, Mendota, California – Mr. Day oversaw the testing and evaluation of the condition of 11 groundwater well pumps and two lift pumps. The project included evaluating the long-term outlook for groundwater quantity and quality underlying the property's well field, evaluating the quantity of surface water available through an existing exchange contract with the U.S. Bureau of Reclamation, and evaluating the viability of short and long-term water transfers to other properties within Westlands Water District.

North In-lieu Project, Arvin-Edison Water Storage District, Arvin, California, Principal-in-Charge – Mr. Day was principal project manager, lead grant writer and administrator on this project. The project includesd development of bi-directional water delivery and banked water return facilities for 650 acres of permanent crops and involves use of surface water in-lieu of groundwater with second priority district use of landowner wells. A 50-60 cfs reverse flow pumping facility has also been added to the District's North Canal to better distribute well water to meet critical drought water supply needs. Mr. Day led the preparation of a successful application for California Department of Water Resources Prop 84 Drought Solicitation Improvement Grant funding though the Kern Integrated Regional Water Management Group. He has also led grant administration and reporting while providing senior engineering input during design, bidding assistance, and construction.

Sediment and Erosion Control Plan Preparation, Wonderful Citrus, Madera, California, Project Manager – Mr. Day worked with Wonderful Citrus as a soil and erosion control engineer to complete and certify Sediment and Erosion Control Plans for properties in the Eastside Water Quality Coalition.

Multi-Benefit Groundwater Storage Project, Arvin-Edison Water Storage District, Arvin, California, Project Manager – Mr. Day served as the project manager and was responsible for project planning, hydrogeology studies, successful application for funding (Proposition 13), California Environmental Quality Act (CEQA) compliance, and design and construction management for a 30-acre expansion of an existing regulation/groundwater recharge reservoir with four new electric-powered deep wells, plus an 80-acre expansion of another existing groundwater storage facility. The project expanded a regulation reservoir, and the groundwater banking capacity for the District and a banking partner.

Canal Lining and Piping Project, James Irrigation District, San Joaquin, California – Mr. Day was design engineer on a project to line and pipe canals that feed James Irrigation District with well water from outside of district boundaries. The project included concrete lining of 9.1 miles of the unlined McMullin Grade Canal and piping 3.8 miles of the Kerman Canal with PVC pipe. Services included design, bidding assistance, and construction review of the successful project that greatly reduced seepage losses, conserved electrical power, and reduced pumping costs.

Integrated Farm Drainage Management Planning Study, Lost Hills Water District, Lost Hills, California, Project Manager – This project involved the supervision of a project team to study and plan changes to Lost Hills Water District's agricultural subsurface drainage water management system from evaporation ponds to Integrated Farm Drainage Management (IFDM), which involved sequential reuse on salt tolerant crops and plants, with a solar evaporator as the final stage. The study and planning included development of a water and salinity model to assist in the planning and conceptual design of IFDM facilities.

Eric A. Abrahamsen, PE

Principal Engineer

Education

- ✓ B.S. Agricultural Engineering, California Polytechnic State University, San Luis Obispo

Registration/Certifications

- ✓ Civil Engineer, California #52000

Affiliations

- ✓ Sustainable Forests and Communities Collaborative
- ✓ American Trails

Areas of Expertise

- ✓ Water Resources
- ✓ Water/Irrigation District Engineering
- ✓ Conservation/Natural Resources Engineering
- ✓ Geographic Information Systems (GIS)

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Professional Summary

Eric Abrahamsen has over 26 years of experience in water resources and agricultural engineering throughout California. He is a principal engineer at Provost & Pritchard specializing in project management, water resources, conservation and natural resources engineering, and irrigation/water district engineering. Mr. Abrahamsen is experienced in the design of water control structures, hydrologic/watershed studies, preparation of agreements and legal descriptions, and is knowledgeable in ArcView/MAP and AutoCAD Map software for geographic information systems (GIS) applications.

Prior to joining the Provost & Pritchard team, Mr. Abrahamsen worked at Merced Irrigation District as a senior engineer and was a field office engineer for the USDA Natural Resources Conservation Service.

Relevant Experience

Conservation/Natural Resources/Recreation Engineering

Seepage Management for San Joaquin River Restoration Program, United States Bureau of Reclamation, CDM Smith, Merced County, California, Project Manager – Mr. Abrahamsen is assisting the U.S. Bureau of Reclamation and the prime contractor staff in seepage management support on the San Joaquin River and bypasses. The scope of work generally includes site evaluations, baseline monitoring, and preliminary and 60% project designs. Specific work has included monitoring of shallow groundwater wells, review of data collection methods reports, agronomic evaluations, preparation of geologic logs and soil sampling from monitor wells and hydraulic conductivity testing, and preparation of appraisal level designs for farms impacted by seepage due to restoration flows. Project is ongoing. (2012-present)

Resource Protection & Erosion Control Designs, USDA Natural Resources Conservation Service, Santa Barbara and San Luis Obispo Counties, California, Project and Resident Engineer – While a field office engineer for the USDA Natural Resources Conservation Service, Mr. Abrahamsen's focus was on the planning, design, and construction management of water distribution, storm runoff, and soil and erosion control systems and structures. His responsibilities included design and construction of drop inlet pipe culverts, pipelines, channels, earthen embankments, sediment and storm water retention basins, gully reclamation projects, reinforced concrete chute and straight drop spillways, stockwater distribution systems and streambank protection projects in the central California coastal region. Work included a preliminary hydrologic investigation for 2,140-acre proposed PL-566 watershed project; damage survey reports after flooding in Southern California; a semi-automated demonstration water distribution system for an 1,850-acre ranch to model for local government agencies, ranchers, and the public, the benefits of time-controlled grazing management within the Morro Bay watershed. (Work prior to P&P, 1989-1993)

Irrigation/Water District Engineering

Railroad Regulating Reservoir Project, Tranquillity Irrigation District, San Joaquin Valley, California, Project Manager – This project involved the

preparation of construction plans for a 74-acre regulating reservoir 4,500-foot-long pipeline and pump stations for construction by the contractor and district forces. Mr. Abrahamsen was responsible for oversight of the boundary survey, easement acquisition, California Environmental Quality Act (CEQA) process, and project design. The initial study, mitigated negative declaration, monitoring and reporting program, and associated noticing as required for CEQA was prepared for approval, which included oversight of project biologist and archeologist, and multiple surveys and mitigation measures regarding endangered species. (2010)

Water Management Plan Preparation, James & Tranquillity Irrigation Districts, Fresno County, California, Project Manager – Mr. Abrahamsen prepared U.S. Bureau of Reclamation required annual water management plans for the 41-square-mile James Irrigation District and 5-year update for 17-square-mile Tranquillity Irrigation District. He performed a district-wide water budget analysis and recommended best management practices for improving operations and water conservation methods. (2010)

Mendota Pool Telemetry System Project Development, Tranquillity Irrigation District, Fresno County, California, Project Manager – Mr. Abrahamsen was responsible for this design/build project, which included the installation of water level telemetry and an alarm system for district agricultural water system at the Mendota Pool. He ensured that the Integrator system was installed in a manner for future expansion for SCADA capabilities and the addition of district domestic water system sites, as well as accessibility of data remotely by San Luis Delta Mendota Water Authority staff. The project included three remote sites and office server with Internet access capabilities, database, alarms and reporting. Mr. Abrahamsen also obtained $50,000 in grant funding for the project from the U.S. Bureau of Reclamation Water Conservation Field Services Program. (2007, $111,000 construction)

Three District Interconnection Study, Tranquillity Irrigation District, San Joaquin Valley, California, Project Manager – As the project manager, Mr. Abrahamsen obtained $25,000 in grant funding from the U.S. Bureau of Reclamation Water Conservation Field Service Program for the Tranquillity Irrigation District. He researched the feasibility of connecting James Irrigation District and Tranquillity Irrigation District's and Tranquillity Irrigation District and Fresno Slough Water District's agricultural irrigation facilities in various locations. Feasible interconnections are planned to be implemented as available funding and agreements between the districts are finalized. (2007/2008)

Groundwater Recharge Project, Lateral K Recharge Basin, James Irrigation District, San Joaquin, California, Project Manager/Lead Design Engineer – This project involved coordinating construction surveys and staking, testing, and inspection with the district and sub-consultants. Mr. Abrahamsen submitted pay estimates for the District's reimbursement to the Department of Water Resources. His responsibilities also included identification, evaluation, location, design and construction of a 220-acre recharge facility capable of producing an average annual new yield of 10,000 acre-feet per year. Facilities included four recharge basins ranging from 70 to 20 acres in size, two canals with a combined flow rate of 205 cfs, and two new turnouts consisting of multiple 48-inch pipelines which deliver water to the project, ultrasonic flow metering, basin delivery structures, and new monitoring wells. Management of groundwater and infiltration data is ongoing.

Groundwater Recharge Project Instrumentation, Lateral K Recharge Basin, James Irrigation District, San Joaquin, California, Project Manager/Lead Design Engineer – Mr. Abrahamsen's responsibilities included identification, evaluation, location, design and construction of a 220-acre recharge facility. Facilities included four recharge basins ranging from 70 to 20 acres in size, two canals with a combined flow rate of 205 cfs, and two new turnouts consisting of multiple 48-inch pipelines which deliver water to the project. The project also included flow metering, basin delivery structures, new monitoring wells, and instrumentation. In addition, the project consisted of instrumentation design, procurement and installation for water level monitoring by direct read pressure transducers with temperature information, and ongoing management of downloaded data, data reduction and graphical presentation to the District. Mr. Abrahamsen also designed and provided installation assistance of ultrasonic flow meters to District staff. Management of groundwater and infiltration data is ongoing. (ALTERNATE WORDING)

Meter Test Facility, James Irrigation District, Fresno County, California, Project Manager – As a result of the U.S. Bureau of Reclamation's Water Conservation Field Services Program, money was award to the district to develop a facility to test their open channel and saddle propeller flow meters. Extensive hydraulic calculation scenarios were performed to ensure that the full range of test flows could be attained. This included comparing system curves with pump curves, variable-frequency drive (VFD) pump scenarios, and hydraulic grade line analyses. (2008)

Main Canal Reregulation Structure, James Irrigation District, Fresno County, California, Project Manager – This project involved modifying an existing structure to capture 40 cfs of spill from the James Irrigation District's main canal. The structure

also reregulates water, acting as a pump structure. Mr. Abrahamsen's responsibilities included site layout and design calculations. This project was designed as a combination long-crested weir and as a pump structure (to Hydraulic Institute Standards). (2007)

Water Augmentation and Storage Consulting, James Irrigation District, Fresno County, California, Project Manager – This project analyzed current James Irrigation District demands to determine if it would be possible to continue farming if Delta supplies were lost. Cropping, weather, and monthly demand patterns were investigated to show the District the necessary measures to break their reliability on the Central Valley Project (CVP). This has resulted in a construction project estimated at $8 million, that could pay for itself in five years.

Merced Irrigation District, Merced County, California, Senior Engineer (1995-2000) – As Merced Irrigation District staff, Mr. Abrahamsen prepared water conveyance facility pipeline and appurtenances designs, reviewed subdivision improvement plans, prepared engineering standard designs, developed standard agreements for encroachments, completed irrigation distribution turnout designs, oversaw implementation of surface water incentive program, and oversaw the installation of California Irrigation Management Information System (CIMIS) weather station. He also conducted field review of projects, managed construction activities, and prepared legal descriptions and deeds. Mr. Abrahamsen served as the agency representative over a 3-year period for a U.S. Army Corps of Engineer flood control facility (1,350 cfs canal turnout and drop structure) on the District Main Canal to insure the facility met local agency concerns and needs during design and construction.

Groundwater Quality Monitoring Program, Pleasant Valley Water District, Coalinga, California, Project Manager – This project consisted of the development of a groundwater-quality monitoring program for the Pleasant Valley Water District. The work included evaluating the quality and thoroughness of water quality data, performing a well canvass, populating a data management system, constructing new monitor wells, and collecting water samples. Mr. Abrahamsen also developed a groundwater-quality monitoring plan, developed new basin management objectives, and updated the District's groundwater management plan in order to develop a comprehensive groundwater-quality monitoring program. Infrastructure needed for the long-term groundwater-monitoring program was installed, which included direct read pressure transducers for gathering water level and temperature information, submersible pumps for gathering water samples, and sensors to measure electrical conductivity on an ongoing basis.

Agricultural Wastewater Reclamation

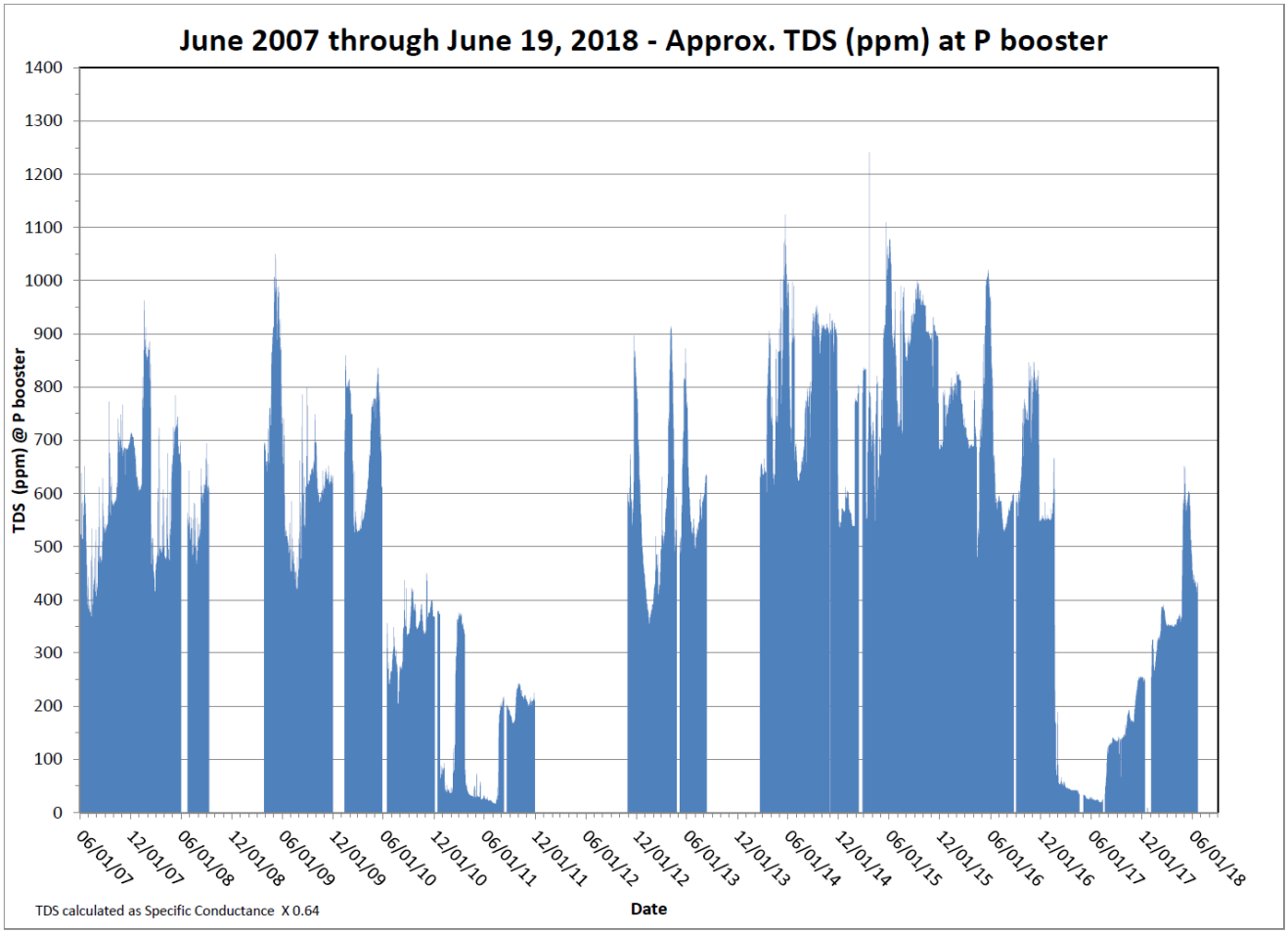
Solar Evaporator Closure Plans & Evaporation Tank Design, Westside Resource Conservation District, Fresno County, California, Project Manager – This project involved preparation of the required "closure plan" documents on behalf the Westside Resource Conservation District for the California Regional Water Quality Control Board, including waste discharge requirements for the closure of two solar evaporators being used by private agricultural operations. The solar evaporators were located on the soil surface for the separation of salts and metals from drainage tile irrigation water. Mr. Abrahamsen's responsibilities included attending regulatory meetings, overseeing final soils investigation, organizing historical data, and making recommendations for closure alternatives. He also designed, and prepared the plans and specifications, and quantities estimate for a concrete masonry solar evaporation tank system to replace one of the previously existing solar evaporators.

Integrated On-Farm Drainage Management (IFDM) spreadsheet development, University of California, Riverside California, Project Engineer – Mr. Abrahamsen provided consulting services to Economics Professor Kurt Schwabe at UC Riverside, in support for economic analysis of solar evaporators and evaporation ponds. The end result of the project was the development of a spreadsheet model.

Regulatory Compliance

Environmental and Permit Documents for Groundwater Recharge Projects, James Irrigation District, Fresno County, California, Project Manager – Mr. Abrahamsen was responsible for the preparation of environmental documents and obtaining regulatory permits for two groundwater recharge projects in James Irrigation District. For the 220 acres "K Basin," an initial study, negative declaration and associated noticing were prepared for project approval. For the 240-acre water augmentation project, the initial study, mitigated negative declaration, monitoring and reporting program, and associated noticing was prepared for approval, which included oversight of the project biologist and archeologist, and multiple reports concerning endangered species, cultural resources, vernal pools and permits. Permit applications included the U.S. Army Corps of Engineers' individual 404 permit for waters and wetlands including Section 7 consultation with U.S. Fish and Wildlife Service's Fish & Game Streambed Alteration Agreement, and the Central Valley Flood Protection Board encroachment. (2002 and 2008-2011)

ATTACHMENT B – June 2007 through June 19, 2018 – Approx. TDS (ppm) at P Booster



ATTACHMENT C – District Crop Production Report Jan-Nov – 2018

District Crop Production Report (Jan-Nov) - 2018

		ACRES
1	ALF SEED	3162.00
2	ALF SEED 19	275.00
3	Alfalfa hay - FORAGE	76.00
4	Almonds - NUTS	7867.00
5	Cotton: Lint (American)	4198.00
6	Cotton: Lint (Upland)	18.00
7	FALLOW	98.00
8	Grapes raisin	613.00
9	Grapes wine	1153.00
10	LETTUCE SEED	67.00
11	Nothing	0.00
12	Onions Dehy.	1685.00
13	Onions Dehy. 19	502.00
14	Pasture Irrigated	5.00
15	Pistachios - NUTS	2428.00
16	Pomegranate - FRUI	139.00
17	SI SORGHUM	2.00
18	Sileage corn - FORAGE	29.00
19	Sudan Hay	52.00
20	TEST TRIAL MIXTURE	40.00
21	Tomatoes (canning)	1141.00
22	Tomatoes (fresh market)	1.00
23	Walnuts	151.00
24	WHEAT GRAIN	19.00
25	Wheat SILEAGE	17.00
26	WINTER FORAGE	27.00
		23765.00

ATTACHMENT D – Appendices E1, E2, and E3 of 2016 Annual Report Mendota Pool Group Pumping and Monitoring Program

Table E-1
Summary of Groundwater Quality Laboratory Results (Shallow Zone Wells)

Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Cations				Anions					Trace Elements								
								Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Wonderful Orchards																									
3730-91 (MW-2)	6/11/2002	JML	1090	-	7.1	-	4	-	-	154	-	-	74	384	17	-	-	0.17	-	-	-	-	-	-	-
3730-91 (MW-2)	3/11/2003	JML	1040	-	6.8	-	-	-	-	185	-	-	75	389	13.2	-	-	0.22	-	-	-	-	-	1.96	-
3730-91 (MW-2)	8/6/2003	JML	900	600	7.0	-	-	-	-	126	-	-	64	366	12.2	-	-	0.22	-	-	-	-	-	0.73	-
3730-91 (MW-2)	8/17/2004	JML	840	538	6.8	-	2.9	-	-	113	-	-	46	305	28	-	-	0.12	-	-	-	-	-	0.87	-
3730-91 (MW-2)	3/14/2005	JML	1480	-	7.0	-	2.9	-	-	120	-	-	67	372	37.6	-	-	0.14	-	-	-	-	-	1.66	-
3730-91 (MW-2)	8/25/2005	JML	1260	-	6.8	-	3.6	-	-	126	-	-	53	207	46.5	-	-	0.13	-	-	-	-	-	1.82	-
3730-91 (MW-2)	3/21/2006	JML	680	-	7.1	-	-	-	-	76	-	-	18	171	14.6	-	-	0.12	-	-	-	-	-	<1	-
3730-91 (MW-2)	9/21/2006	JML	350	224	7.1	-	-	-	-	67	-	-	21	128	10.2	-	-	0.12	-	-	-	-	-	<1	-
3730-91 (MW-2)	8/13/2007	JML	460	-	-	127	3.8	20	8	80	-	38	39	-	13.3	-	-	0.09	-	-	-	-	-	-	-
3730-91 (MW-2)	9/11/2008	JML	540	-	7.1	-	3.4	-	-	92	-	-	35.5	232	23.5	-	-	0.13	-	-	-	-	-	<1	-
3730-91 (MW-2)	8/17/2010	JML	290	-	6.8	-	3.47	-	-	60	-	-	12	131	17.3	-	-	0.09	-	-	-	-	-	-	-
3730-91 (MW-2)	8/17/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-91 (MW-2)	9/27/2011	JML	200	-	6.53	-	1.99	-	-	34	-	-	9.2	97	2.2	-	-	0.07	-	-	-	-	-	-	-
3730-91 (MW-2)	9/27/2011	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-91 (MW-2)	4/17/2012	FGL	254.8	-	7.19	-	-	12	4.1	33	1.7	11	11	110	3.5	0.15	-	0.025	-	0.0063	0.027	0.0028	-	-	0.0349
3730-91 (MW-2)	8/27/2012	JML	470	-	7.5	-	-	-	-	77	-	-	22	192	16.8	-	-	0.13	-	-	-	-	-	-	-
3730-91 (MW-2)	8/27/2012	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.24	-
3730-91 (MW-2)	8/5/2013	JML	400	-	7.23	-	-	18	7	65.3	-	-	19.1	186	12.8	-	-	0.11	-	-	-	-	-	-	-
3730-91 (MW-2)	8/5/2013	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.09	-
3730-91 (MW-2)	8/5/2014	JML	280	-	7.59	-	-	-	-	51	-	-	14	81	8	-	-	0.09	-	-	-	-	-	-	-
3730-91 (MW-2)	8/5/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-93 (MW-3)	6/11/2002	JML	320	-	7.3	-	3.1	-	-	57	-	-	32	104	ND	-	-	0.15	-	-	-	-	-	-	-
3730-93 (MW-3)	3/11/2003	JML	350	-	7.2	-	-	-	-	70	-	-	34	102	ND	-	-	0.18	-	-	-	-	-	0.7	-
3730-93 (MW-3)	8/6/2003	JML	330	200	7.3	-	-	-	-	57	-	-	25	79	ND	-	-	0.16	-	-	-	-	-	ND	-
3730-93 (MW-3)	8/17/2004	JML	640	410	7.4	-	2.8	-	-	83	-	-	64	177	1.3	-	-	0.18	-	-	-	-	-	<0.4	-
3730-93 (MW-3)	3/14/2005	JML	540	-	7.5	-	3.2	-	-	55	-	-	28	73	0.4	-	-	0.13	-	-	-	-	-	<0.4	-
3730-93 (MW-3)	8/25/2005	JML	550	-	7.1	-	3	-	-	57	-	-	39	244	ND	-	-	0.11	-	-	-	-	-	<0.4	-
3730-93 (MW-3)	3/21/2006	JML	640	-	7.2	-	-	-	-	67	-	-	50	98	0.9	-	-	0.12	-	-	-	-	-	<1	-
3730-93 (MW-3)	9/21/2006	JML	460	294	7.2	-	-	-	-	71	-	-	57	116	<0.1	-	-	0.15	-	-	-	-	-	<1	-
3730-93 (MW-3)	8/13/2007	JML	530	-	-	89	2.9	28	10	72	-	62	74	-	1.3	-	-	0.12	-	-	-	-	-	-	-
3730-93 (MW-3)	9/11/2008	JML	370	-	7.2	-	3	-	-	60	-	-	46	104	ND	-	-	0.18	-	-	-	-	-	<1	-
3730-93 (MW-3)	8/17/2010	JML	410	-	7.4	-	3	-	-	66	-	-	54	106	ND	-	-	0.2	-	-	-	-	-	-	-
3730-93 (MW-3)	8/17/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-93 (MW-3)	9/27/2011	JML	460	-	6.88	-	2.98	-	-	70	-	-	63.5	111	0.9	-	-	0.19	-	-	-	-	-	-	-
3730-93 (MW-3)	9/27/2011	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-93 (MW-3)	4/17/2012	FGL	523	-	7.54	-	-	26	8.4	61	3.1	47	69	110	0.6	0.05	-	0.12	-	0.0036	0.182	0.0445	-	-	0.0057
3730-93 (MW-3)	8/27/2012	JML	390	-	7.49	-	-	-	-	56	-	-	41	104	ND	-	-	0.18	-	-	-	-	-	-	-
3730-93 (MW-3)	8/27/2012	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-93 (MW-3)	8/5/2013	JML	300	-	7.26	-	-	13	5	44.6	-	-	26.9	97	<0.2	-	-	0.18	-	-	-	-	-	-	-
3730-93 (MW-3)	8/5/2013	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-93 (MW-3)	8/5/2014	JML	270	-	7.63	-	-	-	-	45	-	-	27	375	<0.1	-	-	0.15	-	-	-	-	-	-	-
3730-93 (MW-3)	8/5/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
2480-93 (MW-4)	6/11/2002	JML	1270	-	8.0	-	13	-	-	278	-	-	170	366	6	-	-	0.28	-	-	-	-	-	-	-
2480-93 (MW-4)	3/11/2003	JML	1300	-	7.8	-	-	-	-	349	-	-	173	417	5.6	-	-	0.33	-	-	-	-	-	1.85	-
2480-93 (MW-4)	8/6/2003	JML	1580	1000	7.8	-	-	-	-	349	-	-	174	415	5.6	-	-	0.33	-	-	-	-	-	1.62	-

Table E-1 (continued)
Summary of Groundwater Quality Laboratory Results (Shallow Zone Wells)

Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Cations				Anions					Trace Elements								
								Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Wonderful Orchards																									
3561-94 (MW-12)	4/17/2012	FGL	1186	-	6.9	-	-	99	26.6	118	5	273	100	200	37	0.13	-	0.15	-	0.062	28.355	4.66	-	-	0.2747
3561-92 (MW-13)	11/16/2006	BSK	1200	770	8.0	210	-	42	8.7	200	<2	120	150	260	51	-	-	0.48	-	-	<0.05	<0.01	-	-	-
3561-92 (MW-13)	11/29/2011	DL	1200	-	8.2	225	-	41	8.6	184	-	115	150	-	7.8	-	-	0.45	-	-	0.01	0.01	-	-	-
3561-92 (MW-13)	4/17/2012	FGL	1192	-	8.19	-	-	44	8.6	206	4	123	150	260	38	0.09	-	0.43	-	0.0067	0.224	0.0137	-	-	0.014
3561-91 (MW-14)	11/17/2006	BSK	2000	1200	7.9	380	-	53	16	380	7	190	270	464	63	-	-	0.75	-	-	<0.05	<0.01	-	-	-
3561-91 (MW-14)	11/29/2011	DL	1960	-	7.5	415	-	43	9.4	354	-	168	230	-	236.8	-	-	0.61	-	-	0.01	0.01	-	-	-
3561-91 (MW-14)	4/17/2012	FGL	1952	-	7.21	-	-	43	8.7	414	2.9	179	240	290	56	0.24	-	0.56	-	0.00022	0.01	0.0013	-	-	0.0072
MW-3730-94	11/29/2011	DL	250	-	6.9	85	-	11	2.6	41	-	10	7.1	-	66.4	-	-	0.12	-	-	0.01	0.01	-	-	-
MW-3730-94	4/17/2012	FGL	350	-	6.74	-	-	28	9.3	37	0.7	37	15	82	41	0.15	-	0.047	-	0.03	8.069	0.51	-	-	0.1149
MW-3921-91	11/29/2011	DL	2710	-	7.8	195	-	300	50.7	267	-	1013	200	-	7.8	-	-	0.63	-	-	0.01	0.01	-	-	-
MW-3921-91	4/17/2012	FGL	3230	-	7.35	-	-	370	65.4	356	7.1	1148	380	180	84	0.13	-	0.81	-	0.015	5.42	0.4	-	-	0.0969
MW-3921-92	4/17/2012	FGL	2878	-	6.92	-	-	270	30.4	352	4.4	668	490	66	140	0.17	-	0.29	-	0.0023	0.023	0.18	-	-	0.0092
MW-3921-93	4/17/2012	FGL	5640	-	7.27	-	-	410	84.3	886	7.5	1721	970	290	180	0.21	-	0.61	-	0.0043	0.018	0.0569	-	-	0.0204
City of Mendota																									
M-2	8/4/1999	FGL	509	320	6.8	-	2.5	25	10	58	2	42	51	200	<0.4	-	<2	0.2	-	-	5.8	0.7	-	<2	-
M-2	9/27/1999	FGL	627	370	6.7	-	2.8	33	14	75	3	59	65	210	<0.4	-	3	0.3	-	-	7.5	1	-	<2	-
M-2	8/23/2000	FGL	1350	780	6.7	160	8.1	35	15	226	4	201	174	190	<0.4	0.2	-	0.5	-	<0.01	8.12	1.21	-	<10	<0.02
M-2	6/28/2001	FGL	1020	650	6.8	130	4.4	42	16	133	4	154	132	160	<0.4	0.1	2	0.36	-	<0.01	8.49	1.24	10	-	<0.02
M-2	6/28/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
M-2	10/1/2001	FGL	1150	730	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M-2	10/1/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
M-2	6/25/2002	FGL	1150	690	6.8	140	5.1	42	17	155	4	197	147	170	<0.4	<0.1	3	0.44	-	<0.01	7.66	1.27	-	-	<0.02
M-2	6/25/2002	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.2	<0.4	-
M-2	7/8/2003	FGL	879	670	7.7	140	-	42	15	127	4	123	121	170	<0.4	0.2	2	0.32	-	<0.01	4.8	0.88	-	-	<0.02
M-2	7/8/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.25	<0.4	-
M-3	4/8/1993	NA	1040	597	6.6	-	3.3	52	20	110	4	150	130	180	-	-	-	-	-	-	-	-	-	-	-
M-3	6/28/2001	FGL	1390	810	6.8	160	6.4	46	18	203	4	218	184	190	<0.4	0.1	3	0.51	-	<0.01	9.27	1.35	10	-	<0.02
M-3	6/28/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
M-3	10/1/2001	FGL	1160	730	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M-3	10/1/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
M-3	7/8/2003	FGL	1760	1060	7.4	190	-	52	20	296	6	305	285	230	<0.4	0.3	3	0.73	-	<0.01	9.4	1.25	-	-	<0.02
M-3	7/8/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.4	<0.4	-
M-4	10/1/2001	FGL	1250	760	6.7	180	5.4	49	19	177	4	196	169	220	<0.4	0.1	3	0.52	-	<0.01	8.57	1.21	-	-	<0.02
M-4	10/1/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.7	<0.4	-
M-4	7/8/2003	FGL	1270	780	7.3	180	-	43	18	222	5	187	196	220	<0.4	0.3	3	0.49	-	<0.01	7.64	0.9	-	-	<0.02
M-4	7/8/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.35	<0.4	-
M-5	10/1/2001	FGL	769	480	6.9	160	3.4	37	16	99	3	88	101	200	<0.4	0.1	<2	0.35	-	<0.01	8.76	1.27	-	-	<0.02
M-5	10/1/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.6	<0.4	-
M-5	7/8/2003	FGL	772	480	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M-6	6/28/2001	FGL	632	430	6.7	150	2.3	35	15	65	3	63	60	180	<0.4	0.1	<2	0.27	-	<0.01	7.59	1.07	3	-	<0.02
M-6	6/28/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-

Table E-1 (continued)
Summary of Groundwater Quality Laboratory Results (Shallow Zone Wells)

Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Cations				Anions					Trace Elements								
								Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Terra Linda Farms																									
TLF-1s	9/18/2007	FGL	1350	840	7.9	390	7.7	44	17	236	2	99	153	470	<0.4	0.1	<2	0.3	-	<0.01	0.58	0.87	-	-	<0.02
TLF-1s	9/19/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	<0.4	-
TLF-1s	9/17/2008	FGL	1160	690	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-1s	5/26/2009	FGL	1080	650	7.3	250	5.6	49	19	181	2	108	120	310	0.4	0.1	<2	0.3	-	0.03	1.23	1.2	6	-	<0.02
TLF-1s	5/26/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
TLF-1s	8/15/2011	FGL	1050	630	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-1s	5/8/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
TLF-1s	5/8/2012	FGL	1200	700	7.4	260	-	37	13	195	2	128	148	320	<1.8	<0.1	<2	0.3	-	<0.01	0.81	0.7	6	-	<0.02
TLF-1s	5/7/2013	FGL	1220	770	7.7	240	-	49	20	206	3	175	140	290	<0.4	0.1	<2	0.3	-	<0.01	1.13	1.37	9	2	<0.02
TLF-1s	9/16/2014	FGL	1080	640	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-2s	6/26/2001	FGL	752	450	7.1	140	3.5	33	14	95	3	80	97	170	<0.4	0.1	<2	0.26	-	<0.01	3.04	0.78	4	-	<0.02
TLF-2s	6/26/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
TLF-2s	10/2/2001	FGL	860	520	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-2s	10/2/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
TLF-2s	7/9/2003	FGL	909	580	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-2s	6/16/2004	FGL	946	590	7.0	150	-	41	19	133	3	127	137	180	<0.4	0.2	<2	0.3	-	<0.01	3.41	1.04	-	-	<0.02
TLF-2s	6/16/2004	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.5	<0.4	-
TLF-2s	10/24/2005	FGL	564	360	7.0	100	-	22	10	73	2	56	76	120	<0.4	0.2	<2	0.2	-	<0.01	2.53	0.42	-	-	<0.02
TLF-2s	10/24/2005	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.4	<0.4	-
TLF-2s	5/21/2007	CLS	860	500	6.69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-2s	9/18/2007	FGL	909	530	7.2	140	4.8	32	15	132	2	113	135	180	<0.4	0.2	<2	0.3	-	<0.01	3.11	0.88	-	-	<0.02
TLF-2s	9/18/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.2	<0.4	-
TLF-2s	9/16/2008	FGL	965	540	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-2s	5/26/2009	FGL	952	560	6.8	140	3.7	48	22	124	3	123	135	170	<0.4	0.2	<2	0.3	-	<0.01	3.95	1.23	4	-	<0.02
TLF-2s	5/26/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
TLF-2s	5/11/2010	FGL	945	560	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-2s	8/15/2011	FGL	719	410	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-2s	5/8/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
TLF-2s	5/8/2012	FGL	891	500	7.3	140	-	30	12	121	2	115	122	160	<1.8	<0.1	<2	0.3	-	0.01	1.53	0.58	4	-	<0.02
TLF-2s	5/8/2013	FGL	954	560	7.1	130	-	41	18	143	3	134	143	160	<0.4	0.2	<2	0.3	-	0.01	3.06	0.88	4	2	<0.02
TLF-3s	6/26/2001	FGL	820	500	7.0	190	3.9	36	14	109	3	73	100	230	<0.4	0.2	<2	0.25	-	<0.01	1.78	0.91	10	-	<0.02
TLF-3s	6/26/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
TLF-3s	10/2/2001	FGL	1030	620	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-3s	10/2/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
TLF-3s	6/26/2002	FGL	1190	750	7.2	240	6.1	39	15	178	3	138	153	290	<0.4	<0.1	<2	0.24	-	0.06	2.19	0.93	-	-	<0.02
TLF-3s	6/26/2002	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.5	<0.4	-
TLF-3s	7/9/2003	FGL	1220	770	8.0	250	-	43	18	196	3	144	171	310	<0.4	0.2	<2	0.28	-	<0.01	2.78	1.21	-	-	<0.02
TLF-3s	7/9/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.1	<0.4	-
TLF-3s	6/16/2004	FGL	1210	740	7.1	230	-	47	20	187	3	148	166	280	0.4	0.2	<2	0.3	-	<0.01	2.87	1.24	-	-	<0.02
TLF-3s	6/16/2004	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.4	<0.4	-
TLF-3s	10/24/2005	FGL	1190	760	6.9	220	-	50	25	155	3	155	155	270	<0.4	0.1	5	0.3	-	0.01	14.1	1.66	-	-	<0.02
TLF-3s	10/24/2005	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.1	<0.4	-
TLF-3s	5/21/2007	CLS	1100	650	6.78	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-3s	9/18/2007	FGL	1210	700	7.1	220	6	42	19	188	3	147	169	270	<0.4	0.1	<2	0.2	-	0.06	2.77	1.04	-	-	<0.02
TLF-3s	9/18/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.6	<0.4	-

Table E-1 (continued)
Summary of Groundwater Quality Laboratory Results (Shallow Zone Wells)

Well Owner and Name	Date	Lab [1]	EC [2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity [3] (mg/L)	SAR	Cations				Anions					Trace Elements								
								Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3 [3] (mg/L)	NO_3 [3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Terra Linda Farms																									
TLF-7s	5/21/2007	CLS	710	430	6.74	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-7s	9/18/2007	FGL	689	430	7.8	180	3.4	30	15	91	3	48	80	220	1.2	0.3	4	0.3	-	<0.01	1.6	1.04	-	-	<0.02
TLF-7s	9/18/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.2	<0.4	-
TLF-7s	9/16/2008	FGL	668	380	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-7s	5/12/2010	FGL	790	430	7.2	190	3.4	36	16	97	3	55	97	240	<0.4	0.3	5	0.3	-	<0.01	1.95	1.38	15	-	0.03
TLF-7s	5/12/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
TLF-7s	5/8/2013	FGL	741	450	6.8	180	-	38	17	97	3	54	89	230	<0.4	0.3	8	0.3	-	<0.01	2.23	1.35	8	1	<0.02
TLF-7s	5/21/2014	FGL	735	440	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-8s	9/12/2001	FGL	989	580	7.5	250	3.6	51	25	124	5	101	109	300	<0.4	0.2	3	0.25	-	<0.01	1.94	1.28	-	-	<0.02
TLF-8s	9/12/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.2	<0.4	-
TLF-8s	6/15/2004	FGL	889	550	7.2	220	-	4	23	112	4	77	108	270	<0.4	0.3	3	0.3	-	<0.01	2.33	1.27	-	-	<0.02
TLF-8s	6/15/2004	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7	<0.4	-
TLF-8s	5/21/2007	CLS	780	480	6.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-8s	9/18/2007	FGL	830	530	7.8	190	3.6	38	18	108	4	86	104	230	<0.4	0.2	2	0.3	-	<0.01	1.59	1.02	-	-	<0.02
TLF-8s	9/18/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.4	<0.4	-
TLF-8s	9/16/2008	FGL	825	480	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-8s	5/12/2010	FGL	938	520	7.2	200	3.5	45	22	116	4	90	122	250	<0.4	0.2	4	0.3	-	<0.01	1.91	1.3	10	-	<0.02
TLF-8s	5/12/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
TLF-8s	5/21/2014	FGL	774	440	7.39	180	-	39	19	95	4	73.6	97	220	<0.4	<0.1	3	0.3	-	<0.01	2.05	1.1	7	-	<0.02
TLF-8s	5/21/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
TLF-9s	9/12/2001	FGL	896	560	7.6	210	3.5	47	22	115	5	99	106	250	<0.4	0.1	<2	0.26	-	<0.01	1.26	1.06	-	-	<0.02
TLF-9s	9/12/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.6	<0.4	-
TLF-9s	7/9/2003	FGL	963	590	7.6	190	-	53	24	110	5	124	132	230	<0.4	0.2	<2	0.23	-	<0.01	1.52	1.23	-	-	<0.02
TLF-9s	7/9/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.1	<0.4	-
TLF-9s	5/21/2007	CLS	910	540	6.81	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-9s	9/18/2007	FGL	868	530	7.8	190	3.3	40	19	101	4	91	108	230	<0.4	0.2	<2	0.3	-	<0.01	1.34	0.96	-	-	<0.02
TLF-9s	9/19/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.7	<0.4	-
TLF-9s	9/16/2008	FGL	827	460	7.3	180	3.4	40	19	103	4	85	95	220	<0.4	0.1	<2	0.3	-	<0.01	1.52	1.04	-	-	0.05
TLF-9s	9/16/2008	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.9	<0.4	-
TLF-9s	5/12/2010	FGL	913	530	7.2	180	3.4	46	21	110	4	98	113	220	<0.4	0.1	<2	0.3	-	<0.01	1.7	1.1	9	-	<0.02
TLF-9s	5/12/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
TLF-9s	5/8/2013	FGL	822	510	7.4	180	-	44	20	105	4	90	96	220	<0.4	0.1	<2	0.3	-	<0.01	1.93	1.11	7	1	<0.02
TLF-9s	5/21/2014	FGL	922	550	7.31	190	-	46	22	102	4	107	103	230	<0.4	<0.1	<2	0.2	-	<0.01	2.19	1.28	5	-	<0.02
TLF-9s	5/21/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
TLF-10s	10/1/2001	FGL	921	550	7.7	200	2.4	62	27	90	5	95	119	240	<0.4	<0.1	<2	0.22	-	0.1	0.49	1.24	-	-	<0.02
TLF-10s	10/1/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.9	<0.4	-
TLF-10s	7/8/2003	FGL	858	530	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-10s	6/15/2004	FGL	1080	690	7.3	210	-	66	29	124	5	149	140	250	<0.4	0.2	<2	0.3	-	<0.01	0.97	1.72	-	-	<0.02
TLF-10s	6/15/2004	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.1	<0.4	-
TLF-10s	10/24/2005	FGL	675	400	7.8	160	-	40	15	72	3	49	87	200	<0.4	<0.1	<2	0.2	-	<0.01	0.67	0.61	-	-	<0.02
TLF-10s	10/24/2005	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	<0.4	-
TLF-10s	5/22/2007	CLS	860	500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-10s	9/18/2007	FGL	922	540	7.2	190	3.3	52	22	111	4	112	118	240	<0.4	<0.1	<2	0.2	-	<0.01	0.7	1.3	-	-	<0.02
TLF-10s	9/18/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.4	<0.4	-
TLF-10s	9/17/2008	FGL	972	520	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table E-1 (continued)
Summary of Groundwater Quality Laboratory Results (Shallow Zone Wells)

Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Cations				Anions					Trace Elements								
								Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Terra Linda Farms																									
TLF-15s	9/18/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	<0.4	-
TLF-15s	5/26/2009	FGL	808	500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-15s	5/11/2010	FGL	817	500	6.9	140	3.6	39	16	106	3	98	110	170	<0.4	0.2	3	0.3	-	<0.01	4.53	1.15	5	-	<0.02
TLF-15s	5/11/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
TLF-15s	8/15/2011	FGL	729	450	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-15s	5/8/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
TLF-15s	5/8/2012	FGL	701	420	7.0	130	-	28	11	88	2	85	92	160	<1.8	0.1	3	0.2	-	<0.01	2.97	0.7	5	-	<0.02
TLF-15s	5/8/2013	FGL	745	460	7.3	140	-	35	14	108	3	86	98	170	<0.4	0.2	3	0.3	-	<0.01	3.9	0.83	5	1	<0.02
TLF-15s	5/21/2014	FGL	758	470	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-16s	9/18/2007	FGL	742	440	7.2	160	3.6	34	16	101	3	75	101	200	<0.4	0.3	<2	0.2	-	<0.01	2.25	1.72	-	-	<0.02
TLF-16s	9/18/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.2	<0.4	-
TLF-16s	9/16/2008	FGL	762	450	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-16s	5/26/2009	FGL	749	460	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-16s	5/11/2010	FGL	903	560	7.0	140	2.8	45	22	93	3	155	102	180	<0.4	0.3	<2	0.2	-	<0.01	5.46	2.76	6	-	<0.02
TLF-16s	5/11/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
TLF-16s	8/15/2011	FGL	958	600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-16s	5/8/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
TLF-16s	5/8/2012	FGL	843	520	6.9	130	-	36	18	93	3	110	110	160	<1.8	0.2	<2	0.3	-	<0.01	3.97	1.99	6	-	<0.02
TLF-16s	5/8/2013	FGL	871	550	7.2	140	-	44	22	103	3	124	117	170	<0.4	0.2	<2	0.3	-	<0.01	4.6	2.51	5	1	<0.02
TLF-16s	9/16/2014	FGL	766	450	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-17s	9/18/2007	FGL	1040	620	8.2	180	5.6	35	14	154	2	130	146	220	<0.4	0.2	<2	0.2	-	<0.01	1.23	1.01	-	-	<0.02
TLF-17s	9/18/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.3	<0.4	-
TLF-17s	9/16/2008	FGL	1070	620	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-17s	5/26/2009	FGL	1050	630	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-17s	5/11/2010	FGL	1010	600	7.0	160	4.2	40	20	130	3	159	125	200	<0.4	0.3	<2	0.3	-	<0.01	3.15	1.6	7	-	<0.02
TLF-17s	5/11/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
TLF-17s	8/15/2011	FGL	732	440	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-17s	5/8/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
TLF-17s	5/8/2012	FGL	975	630	6.9	110	-	49	27	115	3	236	115	140	<1.8	0.2	<2	0.3	-	0.04	8.51	2.31	6	-	<0.02
TLF-17s	5/8/2013	FGL	933	580	7.0	140	-	44	24	127	3	169	115	170	<0.4	0.2	<2	0.3	-	0.03	5.52	1.85	5	1	<0.02
TLF-17s	5/21/2014	FGL	906	570	7.24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TL-11	9/12/2001	FGL	774	450	7.6	210	3.7	35	17	107	3	67	86	260	<0.4	0.2	<2	0.28	-	<0.01	1.63	1.07	-	-	<0.02
TL-11	9/12/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13.7	<0.4	-
Silver Creek Packing Co. (M. Britz TIC)																									
SC-3B	2/27/2002	FGL	847	510	7.3	150	4.4	31	14	117	3	95	111	190	<0.4	<0.1	-	0.29	-	<0.01	3.27	0.66	-	-	0.03
SC-3B	10/17/2002	FGL	1750	1020	6.9	150	-	68	30	245	2	219	325	180	<0.4	0.1	<2	0.28	0.11	0.02	7.78	1.32	-	<2	<0.02
SC-3B	5/21/2007	CLS	1100	610	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SC-3B	9/19/2007	FGL	1640	1010	7.7	150	7.5	64	27	285	2	218	258	190	0.6	0.1	<2	0.39	-	0.11	5	0.93	-	-	0.02
SC-3B	9/19/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.6	<0.4	-
SC-3B	9/16/2008	FGL	1580	890	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SC-3B	5/26/2009	FGL	1440	870	6.8	140	6.9	56	22	242	3	207	236	180	<0.4	0.1	<2	0.3	-	0.67	6.84	0.71	5	-	0.06
SC-3B	5/26/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
SC-3B	5/8/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
SC-3B	5/8/2012	FGL	1110	650	7.0	130	-	30	11	173	2	146	187	150	<1.8	<0.1	<2	0.3	-	<0.01	1.48	0.26	4	-	<0.02

Table E-1 (continued)
Summary of Groundwater Quality Laboratory Results (Shallow Zone Wells)

Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Cations				Anions					Trace Elements								
								Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Coelho/Gardner/Hansen (Vista Verde Farms)																									
CGH-1C (CGH-2s)	6/16/2004	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	<0.4	-
CGH-1C (CGH-2s)	10/25/2005	FGL	1360	840	7.5	370	-	35	10	249	2	112	142	450	<0.4	0.2	<2	0.4	-	<0.01	0.79	0.75	-	-	<0.02
CGH-1C (CGH-2s)	10/25/2005	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.9	<0.4	-
CGH-1C (CGH-2s)	5/22/2007	CLS	1200	630	7.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-1C (CGH-2s)	9/19/2007	FGL	1430	910	8.0	330	7	48	22	234	2	149	176	400	<0.4	0.2	<2	0.4	-	<0.01	1.35	1.55	-	-	<0.02
CGH-1C (CGH-2s)	9/19/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.3	<0.4	-
CGH-1C (CGH-2s)	9/17/2008	FGL	1700	1010	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-1C (CGH-2s)	5/26/2009	FGL	2350	1450	6.9	210	7.8	90	38	350	3	420	370	250	<0.4	0.2	<2	0.6	-	<0.01	2.66	1.77	8	-	<0.02
CGH-1C (CGH-2s)	5/26/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
CGH-1B (CGH-3s)	10/17/2002	FGL	1940	1200	7.1	140	-	56	23	316	3	275	342	180	0.6	<0.1	<2	0.35	0.09	<0.01	2.37	0.86	-	-	<0.02
CGH-1B (CGH-3s)	6/16/2004	FGL	2100	1320	6.6	130	-	82	53	279	4	428	377	150	<0.4	0.3	<2	0.5	-	<0.01	7.15	2.64	-	-	<0.02
CGH-1B (CGH-3s)	6/16/2004	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.7	<0.4	-
CGH-1B (CGH-3s)	10/25/2005	FGL	2110	1320	7.3	200	-	78	19	300	2	308	347	240	<0.4	<0.1	<2	0.4	-	<0.01	1	0.81	-	-	<0.02
CGH-1B (CGH-3s)	10/25/2005	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.6	<0.4	-
CGH-1B (CGH-3s)	5/22/2007	CLS	1200	650	6.59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-1B (CGH-3s)	9/19/2007	FGL	3640	2420	7.6	170	12.4	113	74	689	4	631	670	210	<0.4	<0.1	<2	1.03	-	<0.01	5.17	3.08	-	-	<0.02
CGH-1B (CGH-3s)	9/19/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.4	<0.4	-
CGH-1B (CGH-3s)	5/26/2009	FGL	2850	1780	6.4	150	8.8	90	61	441	4	640	450	190	<0.4	0.2	<2	0.9	-	<0.01	14.1	2.88	10	-	<0.02
CGH-1B (CGH-3s)	5/26/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
CGH-1B (CGH-3s)	5/11/2010	FGL	1540	910	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-1A (CGH-4s)	6/27/2002	FGL	1530	1000	6.9	120	4	70	38	167	4	212	287	150	<0.4	<0.1	<2	0.29	-	<0.01	12.2	2.06	-	-	<0.02
CGH-1A (CGH-4s)	6/27/2002	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.1	<0.4	-
CGH-1A (CGH-4s)	7/9/2003	FGL	1980	1270	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-1A (CGH-4s)	6/16/2004	FGL	2570	1580	6.6	140	-	101	62	350	5	451	520	170	0.6	0.2	<2	0.5	-	<0.01	21.5	3.11	-	-	<0.02
CGH-1A (CGH-4s)	6/16/2004	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.5	<0.4	-
CGH-1A (CGH-4s)	10/24/2005	FGL	3020	2030	6.7	130	-	124	71	353	5	578	570	160	<0.4	<0.1	<2	0.5	-	0.02	13.1	3.59	-	-	<0.02
CGH-1A (CGH-4s)	10/25/2005	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.4	<0.4	-
CGH-1A (CGH-4s)	5/22/2007	CLS	3200	2000	6.44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-1A (CGH-4s)	9/19/2007	FGL	4150	2740	7.2	140	10.6	141	96	665	6	930	840	170	<0.4	<0.1	<2	0.8	-	<0.01	14.9	3.71	-	-	<0.02
CGH-1A (CGH-4s)	9/19/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.1	<0.4	-
CGH-1A (CGH-4s)	9/17/2008	FGL	3960	2480	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-1A (CGH-4s)	5/26/2009	FGL	4010	2900	6.4	140	9.3	148	100	596	7	870	750	180	<0.4	0.1	<2	0.8	-	<0.01	18.8	3.92	8	-	<0.02
CGH-1A (CGH-4s)	5/26/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
CGH-4 (old)	7/13/2000	FGL	3190	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-4 (old)	9/10/2001	FGL	4250	2620	7.9	240	23.6	70	23	892	6	460	940	290	<0.4	0.1	<2	0.98	-	<0.01	0.34	0.46	-	-	<0.02
CGH-4 (old)	9/10/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16	<0.4	-
CGH-3 (CGH-5s)	6/26/2001	FGL	2310	1430	7.3	110	7.9	74	43	345	3	358	413	140	<0.4	0.1	<2	0.39	-	<0.01	2.64	1.84	10	-	<0.02
CGH-3 (CGH-5s)	6/26/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
CGH-3 (CGH-5s)	9/10/2001	FGL	2940	1820	7.4	170	9.5	90	54	462	4	420	610	210	<0.4	0.2	<2	0.48	-	<0.01	2.65	1.75	-	-	<0.02
CGH-3 (CGH-5s)	9/10/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.1	<0.4	-
CGH-3 (CGH-5s)	8/20/2002	CLS	3200	2000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-3 (CGH-5s)	8/20/2002	FGL	3410	2150	7.0	180	11.7	85	52	554	3	440	740	220	<0.4	<0.1	<2	0.54	-	<0.01	1.3	1.35	-	-	<0.02
CGH-3 (CGH-5s)	8/20/2002	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.7	<0.4	-
CGH-3 (CGH-5s)	8/20/2002	TL	3400	2100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table E-1 (continued)
Summary of Groundwater Quality Laboratory Results (Shallow Zone Wells)

Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Cations				Anions					Trace Elements								
								Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Coelho/Gardner/Hansen (Vista Verde Farms)																									
CGH-9 (CGH-7s)	5/11/2010	FGL	1670	990	7.5	420	10.8	31	15	292	2	175	179	510	<0.4	0.2	<2	0.4	-	<0.01	0.3	0.46	7	-	<0.02
CGH-9 (CGH-7s)	5/11/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
CGH-9 (CGH-7s)	8/15/2011	FGL	1440	890	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-9 (CGH-7s)	5/8/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
CGH-9 (CGH-7s)	5/8/2012	FGL	1800	1110	7.2	290	-	38	20	342	3	280	252	350	<1.8	0.1	<2	0.4	-	<0.01	0.21	0.68	10	-	<0.02
CGH-9 (CGH-7s)	5/7/2013	FGL	1530	940	7.7	260	-	37	20	295	3	260	178	310	0.5	0.2	<2	0.4	-	<0.01	0.42	0.69	10	2.54	<0.02
CGH-9 (CGH-7s)	9/16/2014	FGL	3250	2110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-9 (CGH-7s)	9/16/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
CGH-10 (CGH-8s)	6/26/2001	FGL	1010	620	7.9	290	8	25	10	188	2	75	98	350	<0.4	0.2	<2	0.31	-	<0.01	<0.05	0.27	10	-	<0.02
CGH-10 (CGH-8s)	6/26/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
CGH-10 (CGH-8s)	9/10/2001	FGL	1320	830	7.9	460	11.2	31	10	280	2	59	123	560	<0.4	0.3	<2	0.35	-	<0.01	<0.05	0.28	-	-	<0.02
CGH-10 (CGH-8s)	9/10/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	<0.4	-
CGH-10 (CGH-8s)	8/19/2002	CLS	1500	910	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-10 (CGH-8s)	8/19/2002	FGL	1560	1010	7.6	530	11.1	33	13	298	2	80	147	620	<0.4	0.2	<2	0.4	-	<0.01	0.08	0.37	-	-	<0.02
CGH-10 (CGH-8s)	8/19/2002	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	0.4	-
CGH-10 (CGH-8s)	8/19/2002	TL	1600	950	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-10 (CGH-8s)	6/16/2004	FGL	1770	1060	7.4	560	-	50	25	330	3	116	205	680	<0.4	0.3	<2	0.4	-	<0.01	0.21	0.86	-	-	<0.02
CGH-10 (CGH-8s)	6/16/2004	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.5	<0.4	-
CGH-10 (CGH-8s)	10/25/2005	FGL	1860	1190	7.2	520	-	50	26	306	2	172	207	630	0.6	0.2	<2	0.4	-	<0.01	0.36	0.84	-	-	<0.02
CGH-10 (CGH-8s)	10/25/2005	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.5	<0.4	-
CGH-10 (CGH-8s)	5/22/2007	CLS	1500	910	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-10 (CGH-8s)	9/19/2007	FGL	1520	990	8.1	430	12.3	28	13	313	1	129	160	530	<0.4	0.2	<2	0.4	-	<0.01	0.24	0.52	-	-	<0.02
CGH-10 (CGH-8s)	9/19/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11.1	<0.4	-
CGH-10 (CGH-8s)	9/17/2008	FGL	1440	860	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-10 (CGH-8s)	5/11/2010	FGL	1730	1090	7.1	330	5.8	63	41	239	3	350	165	410	<0.4	0.3	<2	0.4	-	<0.01	0.54	2.35	9	-	<0.02
CGH-10 (CGH-8s)	5/11/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
CGH-10 (CGH-8s)	5/8/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
CGH-10 (CGH-8s)	5/8/2012	FGL	1410	870	7.3	300	-	29	17	258	2	196	159	360	<1.8	0.2	<2	0.3	-	<0.01	0.14	0.92	13	-	<0.02
CGH-10 (CGH-8s)	5/7/2013	FGL	1180	710	7.6	220	-	29	18	219	2	181	129	270	<0.4	0.3	<2	0.3	-	<0.01	0.26	0.83	13	1	<0.02
CGH-10 (CGH-8s)	9/16/2014	FGL	1250	760	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-8 (old)	7/22/1997	NA	1000	680	8.2	-	20.65	40	4	540	5	154	511	580	0.82	-	-	0.48	-	-	-	-	-	-	-
CGH-8 (old)	8/25/1999	FGL	3030	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-8 (old)	9/22/1999	FGL	3000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-5 (CGH-9As)	8/3/1999	FGL	3630	2130	8.0	-	16.4	49	20	540	4	280	860	290	<0.4	-	<2	0.7	-	-	0.2	0.3	-	<1	-
CGH-5 (CGH-9As)	7/13/2000	FGL	3290	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-5 (CGH-9As)	10/17/2002	FGL	4870	3000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-5 (CGH-9As)	7/9/2003	FGL	5210	3340	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-5 (CGH-9As)	5/21/2007	CLS	3100	1800	7.51	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-5 (CGH-9As)	9/19/2007	FGL	4620	2810	8.0	260	24.3	74	30	981	4	590	1090	310	<0.4	0.2	2	1	-	<0.01	0.29	0.48	-	-	<0.02
CGH-5 (CGH-9As)	9/19/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15.8	<0.4	-
CGH-5 (CGH-9As)	9/17/2008	FGL	5310	3120	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-5 (CGH-9As)	8/15/2011	FGL	1480	890	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CGH-6C (CGH-10s)	10/17/2002	FGL	2290	1400	7.7	380	-	53	30	290	2	210	330	460	<0.4	0.1	<2	0.46	0.084	0.01	0.42	0.78	-	<2	<0.02
CGH-6C (CGH-10s)	10/25/2005	FGL	1340	820	7.1	300	-	43	26	197	2	179	145	360	<0.4	0.2	<2	0.4	-	<0.01	1.55	1.29	-	-	<0.02

Table E-1 (continued)
Summary of Groundwater Quality Laboratory Results (Shallow Zone Wells)

Well Owner and Name	Date	Lab [1]	EC [2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity [3] (mg/L)	SAR	Cations				Anions					Trace Elements								
								Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3 [3] (mg/L)	NO_3 [3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Meyers Farming																									
MS-4	3/22/1999	BSK	2300	1600	-	-	-	-	-	-	-	-	440	-	-	-	-	0.73	-	-	-	-	-	<2	-
MS-4	3/23/1999	TL	-	1700	-	-	-	-	-	-	-	-	390	-	-	-	-	0.7	-	-	-	-	-	<2	-
MS-4	7/13/2000	FGL	2720	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS-4	6/27/2001	FGL	2830	1720	7.8	340	13	49	36	493	3	495	403	410	<0.4	0.2	<2	0.9	-	<0.01	0.95	0.36	40	-	<0.02
MS-4	6/27/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
MS-4	8/28/2001	TL	2700	1700	-	-	-	-	-	-	-	-	-	-	-	-	-	0.86	-	-	-	-	40	-	-
MS-4	9/10/2001	FGL	2730	1740	7.7	350	14	50	38	539	3	510	350	430	<0.4	0.4	<2	1	-	<0.01	1.84	0.39	-	-	<0.02
MS-4	9/10/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40.7	<0.4	-
MS-6	6/27/2002	FGL	2930	1900	8.0	370	12.7	54	43	516	3	640	360	460	<0.4	0.2	<2	1.1	-	<0.01	0.67	0.34	-	-	<0.02
MS-6	6/27/2002	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	41.2	<0.4	-
MS-6	8/21/2002	CLS	3500	2200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS-6	8/21/2002	FGL	3590	2210	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS-6	8/21/2002	TL	3600	2200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS-6	3/24/2004	TL	2800	1800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS-6	8/4/2005	TL	2000	1300	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS-6	4/25/2007	TL	1500	960	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS-6	5/8/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
MS-6	5/8/2012	FGL	2290	1420	7.4	300	-	40	34	443	3	470	330	360	<1.8	0.1	<2	0.7	-	<0.01	2.33	0.51	30	-	<0.02
MS-6	5/7/2013	FGL	3130	1980	7.7	300	-	72	63	735	4	690	510	370	<0.4	0.2	<2	0.9	-	<0.01	4.5	1.01	19	4.83	<0.02
MS-6	5/21/2014	CAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	-
MS-6	5/21/2014	FGL	4050	2740	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS-6	5/21/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
MS-7	4/30/2002	TL	-	1600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS-7	8/19/2002	CLS	2900	1800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS-7	8/19/2002	FGL	2930	1890	7.3	370	14	49	38	538	2	460	430	450	<0.4	0.2	<2	0.98	-	<0.01	0.53	0.38	-	-	<0.02
MS-7	8/19/2002	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	38.7	<0.4	-
MS-7	8/19/2002	TL	-	-	-	-	15.2	49	37	580	6	470	400	440	-	-	-	-	-	-	-	-	-	-	-
MS-7	3/24/2004	TL	2900	1900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS-7	8/4/2005	TL	2200	1400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS-7	4/23/2007	TL	1400	920	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS-7	5/8/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
MS-7	5/8/2012	FGL	2330	1440	7.9	340	-	31	24	478	2	430	350	410	<1.8	0.2	<2	0.8	-	<0.01	0.39	0.21	29	-	<0.02
MS-7	5/7/2013	FGL	2480	1530	8.1	340	-	43	33	704	3	470	360	410	<0.4	0.3	<2	0.8	-	<0.01	0.94	0.33	24	3.55	<0.02
MS-7	5/21/2014	CAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	-
MS-7	5/21/2014	FGL	3090	1990	8.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS-7	5/21/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
S-1	8/3/1998	BSK	6100	4300	-	-	-	-	-	-	-	-	1400	-	-	-	-	1.2	-	-	-	-	-	-	-
S-1	1/4/1999	BSK	7200	5600	-	-	-	-	-	-	-	-	1900	-	-	-	-	1.3	-	-	-	-	-	-	-
S-1	4/1/1999	BSK	7200	5200	-	-	-	-	-	-	-	-	2000	-	-	-	-	1.1	-	-	-	-	-	<2	-
S-1	8/5/1999	FGL	7470	5100	6.7	-	17.3	150	168	1300	11	1380	1610	230	<0.4	-	<2	1.4	-	-	3.4	2.2	-	<2	-
S-1	7/8/2003	FGL	5990	4100	7.8	240	-	116	112	1170	7	1510	1170	290	<0.4	<0.1	<2	1.65	-	<0.01	1.8	1.18	-	-	<0.02
S-1	7/8/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
S-2	8/3/1998	BSK	6500	4900	-	-	-	-	-	-	-	-	960	-	-	-	-	3.4	-	-	-	-	-	-	-
S-2	1/4/1999	BSK	5900	4600	-	-	-	-	-	-	-	-	1000	-	-	-	-	3.4	-	-	-	-	-	<2	-

Table E-1 (continued)
Summary of Groundwater Quality Laboratory Results (Shallow Zone Wells)

Well Owner and Name	Date	Lab [1]	EC [2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity [3] (mg/L)	SAR	Cations				Anions					Trace Elements								
								Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3 [3] (mg/L)	NO_3 [3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Meyers Farming																									
P-4	4/1/1999	BSK	8900	6200	-	-	-	-	-	-	-	-	2600	-	-	-	-	1.2	-	-	-	-	-	<2	-
P-4	8/8/2006	FGL	8730	5800	7.6	250	-	185	178	1820	8	1610	2160	300	<0.4	<0.1	3	1.3	-	<0.01	4.26	1.33	-	-	<0.02
P-4	8/8/2006	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33.1	<0.4	-
P-4	9/18/2008	FGL	33200	23600	6.4	300	31	643	955	5300	29	4500	9800	400	<0.4	<0.5	18	4.4	-	<0.01	30.7	3.69	-	-	<0.02
P-4	9/18/2008	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	39.5	<0.4	-
P-4	9/16/2014	FGL	7990	5470	6.7	250	-	183	186	1450	8	1780	1590	310	<0.4	<0.1	5	1.2	-	<0.01	17.2	4.11	40	-	<0.02
P-5	8/3/1998	BSK	6200	4000	-	-	-	-	-	-	-	-	1200	-	-	-	-	1.1	-	-	-	-	-	-	-
P-5	1/4/1999	BSK	5300	4000	-	-	-	-	-	-	-	-	1100	-	-	-	-	1.3	-	-	-	-	-	-	-
P-5	4/1/1999	BSK	6000	4200	-	-	-	-	-	-	-	-	1300	-	-	-	-	1	-	-	-	-	-	<2	-
P-6	8/3/1998	BSK	37000	-	-	-	-	-	-	-	-	-	8800	-	-	-	-	6.5	-	-	-	-	-	-	-
P-6	1/4/1999	BSK	31000	-	-	-	-	-	-	-	-	-	7600	-	-	-	-	8	-	-	-	-	-	-	-
P-6	4/1/1999	BSK	35000	-	-	-	-	-	-	-	-	-	8600	-	-	-	-	8.3	-	-	-	-	-	-	-
Five Star (Casaca Vineyards, Solo Mio Farms, & Daddy's Pride Farming)																									
FS-1	10/19/1993	NA	1520	907	7.3	-	7.4	36	26	240	2	200	240	241	-	-	-	-	-	-	-	-	-	-	-
FS-1	9/12/2001	FGL	1030	590	8.0	200	6.6	29	15	176	2	102	139	240	<0.4	0.2	<2	0.36	-	<0.01	0.3	0.4	-	-	<0.02
FS-1	9/12/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	<0.4	-
FS-1	8/21/2002	CLS	1200	670	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FS-1	8/21/2002	FGL	1160	710	7.9	220	7.1	29	15	190	2	110	166	260	<0.4	0.1	<2	0.36	-	<0.01	0.24	0.39	-	-	<0.02
FS-1	8/21/2002	TL	1200	680	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FS-1	9/21/2007	FGL	856	520	8.0	170	9.3	14	7	171	1	78	116	200	<0.4	0.4	<2	0.25	-	<0.01	0.19	0.2	-	-	<0.02
FS-1	9/21/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16.7	<0.4	-
FS-1	9/15/2008	FGL	1020	560	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FS-1	5/27/2009	FGL	1060	620	7.5	190	6.8	32	15	187	2	105	157	230	<0.4	0.2	<2	0.4	-	<0.01	1.06	0.5	16	-	<0.02
FS-1	5/27/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
FS-1	5/9/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
FS-1	5/9/2012	FGL	923	540	7.4	160	-	21	11	168	2	99	144	200	<1.8	0.2	<2	0.4	-	<0.01	0.27	0.43	13	-	<0.02
FS-1	5/7/2013	FGL	1040	610	8.0	160	-	32	17	178	3	151	142	200	0.5	0.2	<2	0.4	-	<0.01	0.6	0.54	11	2	<0.02
FS-1	5/20/2014	FGL	1080	650	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FS-2	10/3/2001	FGL	1190	740	7.4	180	4.4	51	27	157	3	202	134	210	<0.4	0.1	<2	0.36	-	<0.01	1.24	1.17	-	-	<0.02
FS-2	10/3/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13.9	<0.4	-
FS-2	5/14/2007	CLS	840	470	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FS-2	9/15/2008	FGL	1050	560	7.1	150	5.2	36	18	154	3	134	143	190	<0.4	0.2	<2	0.4	-	<0.01	1.1	0.65	-	-	<0.02
FS-2	9/15/2008	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.77	<0.4	-
FS-2	5/27/2009	FGL	1270	730	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FS-2	5/13/2010	FGL	1350	750	7.2	180	7.6	35	18	222	3	119	242	220	<0.4	0.3	<2	0.4	-	<0.01	1.19	0.75	10	-	<0.02
FS-2	5/13/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
FS-2	5/9/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
FS-2	5/9/2012	FGL	1140	660	7.2	180	-	30	19	200	3	160	173	220	<1.8	0.1	<2	0.4	-	<0.01	1.18	0.7	12	-	<0.02
FS-2	5/7/2013	FGL	1350	780	7.6	180	-	37	19	235	3	155	233	220	<0.4	0.2	<2	0.4	-	<0.01	1.08	0.74	10	2.58	<0.02
FS-2	5/20/2014	CAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	-
FS-2	5/20/2014	FGL	1400	830	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FS-2	5/20/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
FS-3	9/12/2001	FGL	1680	1020	8.0	400	11.9	30	17	330	3	181	194	490	<0.4	0.2	<2	0.5	-	<0.01	1.13	0.68	-	-	<0.02
FS-3	9/12/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	<0.4	-

Table E-1 (continued)
Summary of Groundwater Quality Laboratory Results (Shallow Zone Wells)

Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Cations				Anions					Trace Elements								
								Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Five Star (Casaca Vineyards, Solo Mio Farms, & Daddy's Pride Farming)																									
FS-5	5/7/2013	FGL	1110	660	7.5	150	-	40	21	176	3	172	157	190	<0.4	0.2	<2	0.4	-	<0.01	2.15	0.66	12	1	<0.02
FS-5	5/20/2014	FGL	1080	640	7.83	160	-	32	16	156	3	132	150	200	<0.4	<0.1	<2	0.3	-	<0.01	1.52	0.48	12	-	<0.02
FS-5	9/16/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
FS-6	9/12/2001	FGL	2340	1390	7.9	260	9.6	63	39	392	3	330	401	320	<0.4	0.2	<2	0.52	-	<0.01	0.42	0.6	-	-	<0.02
FS-6	9/12/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23.2	<0.4	-
FS-6	7/13/2009	FGL	1960	1150	7.7	260	11.5	39	25	374	2	310	287	320	<0.4	0.1	<2	0.6	-	<0.01	0.41	0.32	18	-	<0.02
FS-6	7/13/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
FS-6	5/13/2010	FGL	1970	1180	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FS-6	5/10/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
FS-6	5/10/2012	FGL	1960	1250	7.3	240	-	53	38	365	3	420	268	290	<1.8	0.1	<2	0.5	0.11	<0.01	0.62	1.17	15	-	<0.02
FS-6	5/7/2013	FGL	2220	1430	7.4	270	-	62	43	406	3	500	310	330	<0.4	0.1	<2	0.6	-	<0.01	1.18	1.11	17	3.06	<0.02
FS-6	5/20/2014	CAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	-
FS-6	5/20/2014	FGL	1900	1200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FS-6	5/20/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
FS-7	10/3/2001	FGL	2500	1600	7.3	280	7.9	83	57	380	3	489	374	340	<0.4	0.1	<2	0.53	-	<0.01	1.85	1.35	-	-	<0.02
FS-7	10/3/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17.7	<0.4	-
FS-7	9/21/2007	FGL	2260	1490	7.8	420	9	69	58	418	3	390	250	510	<0.4	0.2	<2	0.53	-	<0.01	6.45	2.1	-	-	<0.02
FS-7	9/21/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17.2	<0.4	-
FS-7	9/16/2008	FGL	2190	1330	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FS-7	7/13/2009	FGL	2330	1450	7.5	290	9.5	62	50	415	3	530	290	360	<0.4	<0.1	<2	0.7	-	<0.01	2.66	1.18	15	-	<0.02
FS-7	7/13/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
FS-7	5/13/2010	FGL	2350	1490	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FS-7	5/7/2013	FGL	1760	1120	7.4	240	-	43	38	319	3	420	193	300	<0.4	0.2	<2	0.5	-	<0.01	1.6	1.12	11	2	<0.02
FS-7	5/20/2014	FGL	2220	1470	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FS-8	10/3/2001	FGL	2240	1310	7.7	240	12.1	43	24	400	3	210	444	290	<0.4	0.2	<2	0.6	-	<0.01	0.63	0.38	-	-	<0.02
FS-8	10/3/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19	<0.4	-
FS-8	5/14/2007	CLS	1200	760	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FS-8	9/16/2008	FGL	1800	1000	7.6	210	10.2	34	19	299	2	181	314	260	<0.4	0.3	<2	0.5	-	<0.01	0.8	0.35	-	-	<0.02
FS-8	9/16/2008	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15.97	<0.4	-
FS-8	5/27/2009	FGL	2140	1250	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FS-8	5/13/2010	FGL	2040	1190	7.7	230	9.6	46	28	334	2	280	360	280	<0.4	0.2	<2	0.6	-	<0.01	0.57	0.52	17	-	<0.02
FS-8	5/13/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
FS-8	5/7/2013	FGL	2130	1320	7.5	220	-	56	38	382	4	410	360	270	1.1	0.2	<2	0.6	-	<0.01	2.51	1.18	15	3.54	<0.02
FS-8	5/20/2014	CAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	-
FS-8	5/20/2014	FGL	2000	1190	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FS-8	5/20/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
FS-9	9/12/2001	FGL	2090	1290	7.9	310	9.8	44	38	368	3	343	286	380	<0.4	0.2	<2	0.56	-	<0.01	1.14	1.14	-	-	<0.02
FS-9	9/12/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17.6	<0.4	-
FS-9	5/14/2007	CLS	1500	920	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FS-9	9/16/2008	FGL	1890	1130	7.3	330	8.9	39	31	308	3	300	223	400	<0.4	0.3	<2	0.5	-	<0.01	2.17	1.72	-	-	0.03
FS-9	9/16/2008	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13.1	<0.4	-
FS-9	5/27/2009	FGL	2130	1340	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FS-9	5/7/2013	FGL	1540	990	7.3	190	-	28	27	283	3	310	166	230	0.4	0.3	<2	0.4	-	<0.01	1.39	1.22	11	2.06	<0.02
FS-9	5/20/2014	CAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	-

Table E-1 (continued)
Summary of Groundwater Quality Laboratory Results (Shallow Zone Wells)

Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Cations				Anions					Trace Elements								
								Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Coelho West																									
CW-1	5/20/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
CW-1	9/16/2014	FGL	-	-	7.59	-	-	-	-	-	-	-	-	-	-	-	-	-	0.067	-	-	-	-	-	-
CW-2	9/12/2001	FGL	1780	1100	8.3	440	17.9	18	11	391	2	183	202	500	<0.4	0.2	<2	0.61	-	<0.01	1.24	0.2	-	-	<0.02
CW-2	9/12/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30.5	<0.4	-
CW-2	6/25/2002	FGL	1100	670	8.5	250	13.4	9	6	212	1	108	133	300	<0.4	0.1	<2	0.46	-	<0.01	1.1	0.06	-	-	<0.02
CW-2	6/25/2002	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19.7	<0.4	-
CW-2	8/21/2002	CLS	1200	660	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CW-2	8/21/2002	FGL	1160	710	8.5	250	14	10	7	236	<1	120	133	290	<0.4	0.2	-	0.43	0.0245	<0.01	0.09	0.05	-	-	<0.02
CW-2	8/21/2002	TL	1200	690	-	-	14.8	10	7	250	2	110	140	300	-	-	-	-	-	-	-	-	-	-	-
CW-2	5/15/2007	CLS	1500	860	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CW-2	9/20/2007	FGL	1460	910	8.5	320	14.5	19	12	327	<1	178	162	380	<0.4	0.3	<2	0.44	0.0436	<0.01	0.19	0.08	-	-	<0.02
CW-2	9/20/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18.7	<0.4	-
CW-2	9/16/2008	FGL	1510	870	8.1	330	11.8	20	13	276	1	140	180	410	<0.4	0.2	<2	0.6	0.0637	<0.01	2.11	0.12	-	-	<0.02
CW-2	9/16/2008	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25.2	<0.4	-
CW-2	5/9/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
CW-2	5/9/2012	FGL	1490	890	7.9	350	-	18	12	323	2	159	182	430	<1.8	0.2	<2	0.6	0.049	<0.01	0.35	0.14	33	-	<0.02
CW-2	9/16/2014	FGL	1250	750	7.85	290	-	17	12	251	1	125	134	350	<0.4	0.2	<2	0.5	0.0413	<0.01	1.11	0.22	21	-	<0.02
CW-2	9/16/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
CW-3	8/24/2000	FGL	1570	920	8.1	300	18.2	13	8	338	1	204	156	340	<0.4	0.2	-	0.5	0.041	<0.01	0.73	0.12	-	-	<0.02
CW-3	6/25/2001	FGL	1710	1050	8.0	330	16.8	16	10	348	2	232	188	400	<0.4	0.3	<2	0.51	-	<0.01	0.8	0.2	30	-	<0.02
CW-3	6/28/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
CW-3	6/17/2002	TL	1500	920	7.6	300	16	16	11	340	3	180	190	370	<2	-	-	0.56	0.045	<0.05	1.4	0.26	-	-	<0.05
CW-3	8/21/2002	CLS	1600	940	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CW-3	8/21/2002	FGL	1650	1020	8.1	350	16.9	15	9	336	1	208	187	390	<0.4	0.3	-	0.56	-	<0.01	0.35	0.15	-	-	0.02
CW-3	8/21/2002	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28.4	<0.4	-
CW-3	8/21/2002	TL	1700	999	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CW-3	7/9/2003	FGL	1270	810	7.5	170	-	29	25	198	2	250	155	210	<0.4	0.5	-	0.42	-	<0.01	6.58	1.26	-	-	0.05
CW-3	7/9/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.25	<0.4	-
CW-3	10/27/2005	FGL	1410	880	7.4	250	-	23	16	257	2	198	169	310	<0.4	0.3	<2	0.5	-	<0.01	2.45	0.46	-	-	<0.02
CW-3	10/27/2005	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
CW-3	10/27/2006	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17.5	<0.4	-
CW-3	5/15/2007	CLS	1800	1100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CW-3	9/21/2007	FGL	1990	1240	8.4	500	17.5	26	17	467	1	211	225	610	<0.4	0.4	<2	0.55	0.09	<0.01	0.69	0.48	-	-	<0.02
CW-3	9/21/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	26	<0.4	-
CW-3	9/16/2008	FGL	1970	1170	8.0	490	16.6	21	13	393	2	189	218	580	<0.4	0.4	<2	0.7	0.075	<0.01	0.42	0.33	-	-	<0.02
CW-3	9/16/2008	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25.87	<0.4	-
CW-3	5/27/2009	FGL	1780	1040	8.0	430	16.6	17	10	348	1	175	202	530	0.7	0.4	<2	0.7	0.0549	<0.01	0.43	0.29	27	-	<0.02
CW-3	5/27/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
CW-3	5/9/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.1	-
CW-3	5/9/2012	FGL	2200	1370	7.7	520	-	27	19	479	2	320	280	640	<1.8	0.2	<2	0.6	0.0954	0.02	0.77	0.62	28	-	<0.02
CW-3	5/7/2013	FGL	2140	1340	7.8	540	-	27	18	544	2	280	210	660	1	0.3	<2	0.6	-	<0.01	0.65	0.57	26	2.96	<0.02
CW-3	5/20/2014	CAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	-
CW-3	5/20/2014	FGL	1590	1010	8.16	370	-	13	9	327	1	183	175	460	<0.4	<0.1	<2	0.5	-	<0.01	0.41	0.24	28	-	<0.02
CW-3	5/20/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
CW-3	9/16/2014	FGL	-	-	8.31	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0456	-	-	-	-	-	-

Table E-1 (continued)
Summary of Groundwater Quality Laboratory Results (Shallow Zone Wells)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Coelho West																									
CW-5	5/9/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
CW-5	5/9/2012	FGL	1420	850	8.1	320	-	6	4	327	1	155	158	390	<1.8	0.3	<2	0.4	0.0294	<0.01	0.26	0.11	16	-	<0.02
CW-5	5/7/2013	FGL	1120	680	8.5	250	-	5	3	266	1	-	-	310	0.4	-	<2	0.4	-	<0.01	0.24	0.06	15	2	0.06
CW-5	5/20/2014	FGL	1930	1180	7.92	420	-	11	7	412	2	251	198	520	<0.4	<0.1	<2	0.5	-	<0.01	0.58	0.2	19	-	<0.02
CW-5	5/20/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
CW-5	9/16/2014	FGL	-	-	7.83	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0693	-	-	-	-	-	-

1. Laboratory Abbreviations: BAS - Basic Laboratory; BD - Betz Dearborn; BSK - BSK Analytical Laboratories, Fresno; CAL - Caltest Analytical Laboratories, Napa; CLS - California Laboratory Services, Rancho Cordova; DL - Dellavalle Labs; FGL - Fruit Growers Laboratory, Santa Paula; JML - JM Lord, Fresno; NA - Not Available; OBL - Olson Biochemistry Laboratories of South Dakota State University, Brookings, SD; SDAL - South Dakota Agricultural Laboratories; TL - The Twining Laboratories, Inc., Fresno.; UAG - U.S. Agricultural Consultants and Laboratories, Burbank; USGS - U.S. Geological Survey

2. Constituent Abbreviations: EC - Electrical Conductivity; TDS - Total Dissolved Solids; SAR - Sodium Absorption Ratio; Ca - Calcium; Mg - Magnesium; Na - Sodium; K - Potassium; SO4 - Sulfate; Cl - Chloride; HCO3 - Bicarbonate; NO3 - Nitrate; F - Fluoride; As - Arsenic; B - Boron; Ba - Barium; Cu - Copper; Fe - Iron; Mn - Manganese; Mo - Molybdenum; Se - Selenium; Zn - Zinc

3. Electrical Conductivity at 25°C

4. HCO3 , Total Alkalinity and NO3 reported as HCO3 , CaCO3 and NO3 respectively. Some 2008 NO3 results may include NO2 in reported value.

NA = Not Available; ND = Non Detect (detection limit unknown)

Table E-2
Summary of Groundwater Quality Laboratory Results (Deep Zone, Composite and Lower Aquifer)

Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Cations				Anions					Trace Elements								
								Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Central California ID																									
5A	8/1/1990	NA	630	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5A	8/1/1991	NA	794	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5A	8/1/1992	NA	584	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5A	8/1/1996	NA	828	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5A	6/9/1997	NA	710	430	8.3	-	-	16	5	120	2	98	83	134	<0.4	-	-	0.3	-	-	0.54	0.31	-	-	-
5A	8/4/1999	FGL	688	450	7.9	-	6	16	5	107	2	97	85	150	<0.4	-	2	0.3	-	-	0.05	0.03	-	<2	-
5A	9/29/1999	FGL	587	350	7.7	-	4	23	8	88	2	70	79	140	<0.4	-	<2	0.2	-	-	0.6	0.3	-	<2	-
5A	6/7/2001	CCID	730	460	7.9	110	7.5	18	5.3	140	2	110	92	134	<10	-	-	0.2	-	-	-	-	-	-	-
5A	9/30/2002	BSK	910	590	7.7	120	-	19	5	180	2	150	98	120	ND	-	-	0.4	-	-	-	-	-	-	-
5A	8/25/2003	BSK	620	390	8.1	110	-	26	8	110	ND	68	84	110	ND	-	-	0.2	-	-	-	-	-	-	-
5A	7/14/2004	BSK	880	580	8.1	-	-	20	5	180	2	170	100	130	ND	-	-	0.3	-	-	-	-	-	2	-
5A	8/24/2007	BSK	890	570	8.2	120	-	15	3	160	2.2	170	100	120	ND	-	-	0.35	-	-	-	-	-	ND	-
5A	9/2/2008	NA	1100	-	8.2	120	-	24	5	200	2.7	230	110	146	ND	-	-	0.46	-	-	-	-	-	ND	-
5A	7/16/2009	BSK	1200	700	8.3	140	-	26	5.1	210	2.8	240	110	140	ND	-	-	0.5	-	-	-	-	-	ND	-
5A	9/23/2010	BSK	660	390	8.3	120	-	20	5.9	100	2.1	85	82	120	ND	-	-	0.22	-	-	-	-	-	ND	-
5A	3/2/2012	BSK	1100	660	8.2	130	-	23	4.6	210	2.9	220	110	130	ND	-	-	0.47	-	-	-	-	-	ND	-
5A	8/9/2013	BSK	1200	760	8.3	140	-	34	6.1	220	3.2	270	120	209	ND	-	-	0.57	-	-	-	-	-	ND	-
5A	8/19/2014	BSK	1300	820	8.2	130	-	30	5.2	240	3.2	300	130	159	<5	-	-	0.64	-	-	-	-	-	<1	-
12C	6/7/2001	CCID	1700	1200	7.3	120	5.7	86	42	260	4	420	260	146	ND	-	-	0.5	-	-	-	-	-	-	-
12C	9/30/2002	BSK	1900	1300	6.8	130	-	82	41	270	6	430	250	130	ND	-	-	0.6	-	-	-	-	-	-	-
12C	8/25/2003	BSK	1400	1000	7.4	120	-	68	35	200	5	330	180	120	ND	-	-	0.5	-	-	-	-	-	-	-
12C	7/15/2004	BSK	1800	1300	7.4	-	-	89	43	280	5	490	250	140	ND	-	-	0.6	-	-	-	-	-	4	-
12C	8/24/2007	BSK	1800	1400	7.4	140	-	69	33	230	3.9	550	280	140	ND	-	-	0.7	-	-	-	-	-	ND	-
12C	9/2/2008	NA	2200	-	7.6	140	-	91	46	310	5.5	560	270	171	ND	-	-	0.94	-	-	-	-	-	ND	-
12C	7/16/2009	BSK	2300	1500	8.0	160	-	98	48	340	5.6	600	290	160	ND	-	-	1	-	-	-	-	-	ND	-
12C	9/23/2010	BSK	2200	1600	7.9	160	-	90	45	320	5.1	610	290	160	ND	-	-	1.1	-	-	-	-	-	ND	-
12C	3/2/2012	BSK	2100	1400	7.6	150	-	95	48	330	5.6	540	260	150	ND	-	-	1.1	-	-	-	-	-	ND	-
12C	8/9/2013	BSK	2400	1600	8.0	180	-	100	50	350	5.6	630	300	268	ND	-	-	1.2	-	-	-	-	-	ND	-
12C	8/19/2014	BSK	2500	1700	7.8	160	-	100	49	390	5.4	690	310	195	<10	-	-	1.4	-	-	-	-	-	<1	-
15	7/15/1960	NA	813	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	7/15/1961	NA	1050	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	7/15/1965	NA	753	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	7/15/1972	NA	659	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	7/15/1974	NA	641	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	7/15/1975	NA	600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	7/15/1976	NA	641	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	4/15/1977	NA	528	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	7/15/1978	NA	500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	4/15/1979	NA	550	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15A	7/15/1980	NA	550	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15A	4/15/1981	NA	845	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15A	7/15/1982	NA	863	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15A	4/15/1984	NA	847	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15A	7/15/1987	NA	800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15A	7/15/1988	NA	860	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15A	7/1/1989	NA	951	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15A	8/1/1990	NA	1170	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table E-2 (continued)
Summary of Groundwater Quality Laboratory Results (Deep Zone, Composite and Lower Aquifer)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Central California ID																									
28A	4/15/1977	NA	825	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28A	7/15/1978	NA	1172	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28A	4/15/1979	NA	800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28A	4/15/1981	NA	1159	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28A	7/15/1982	NA	1000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28A	4/15/1984	NA	962	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28A	7/15/1987	NA	850	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28A	7/15/1988	NA	850	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28A	7/1/1989	NA	1118	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28A	8/1/1990	NA	1382	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28A	8/1/1991	NA	1335	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28A	8/1/1992	NA	1304	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28A	8/1/1994	NA	1480	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28B	2/1/1995	NA	1160	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28B	8/1/1996	NA	1370	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28B	6/9/1997	NA	-	890	-	-	-	-	-	175	-	314	137	-	-	-	-	-	-	-	<0.05	0.96	-	-	-
28B	8/4/1999	FGL	1400	940	6.9	-	3.9	70	32	157	5	310	153	200	<0.4	-	3	0.4	-	-	11.4	1.5	-	<2	-
28B	9/29/1999	FGL	1410	960	6.7	-	3.6	76	36	152	6	326	162	210	<0.4	-	<2	0.4	-	-	0.05	0.01	-	<2	-
28C	7/15/2004	BSK	1300	850	8.0	-	-	16	3	280	3	220	180	160	-	-	-	0.8	-	-	-	-	-	4	-
28C	8/24/2007	BSK	1300	830	8.1	150	-	14	2	250	2.7	220	180	150	ND	-	-	0.76	-	-	-	-	-	ND	-
28C	9/2/2008	NA	1400	-	8.1	150	-	15	3	280	3	220	180	183	ND	-	-	0.83	-	-	-	-	-	ND	-
28C	7/27/2009	BSK	1400	860	8.1	170	-	14	2.6	270	3	230	200	170	ND	-	-	0.85	-	-	-	-	-	ND	-
28C	9/23/2010	BSK	1800	1100	8.2	150	-	28	5.6	350	3.7	410	230	150	ND	-	-	0.73	-	-	-	-	-	ND	-
28C	3/2/2012	BSK	1400	860	8.1	250	-	17	3.1	300	3.3	250	200	150	ND	-	-	0.89	-	-	-	-	-	ND	-
28C	8/9/2013	BSK	1500	930	8.3	160	-	17	2.9	290	3.3	250	200	238	ND	-	-	0.86	-	-	-	-	-	ND	-
32	7/15/1964	NA	416	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32	7/15/1968	NA	653	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32A	7/15/1970	NA	745	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32A	7/15/1972	NA	900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32A	7/15/1974	NA	1030	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32A	7/15/1975	NA	1050	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32A	7/15/1976	NA	941	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32A	4/15/1977	NA	900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32A	4/15/1979	NA	800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32B	4/15/1981	NA	900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32B	7/15/1982	NA	900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32B	4/15/1984	NA	991	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32B	7/15/1987	NA	1000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32B	7/15/1988	NA	1548	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32B	7/1/1989	NA	1674	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32B	8/1/1990	NA	2060	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32B	8/1/1991	NA	1789	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32B	8/1/1992	NA	1370	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32B	8/1/1996	NA	2090	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32B	6/9/1997	NA	2000	1400	7.9	-	-	110	36	270	7	610	200	195	<0.4	-	-	1.2	-	-	<0.05	2.5	-	-	-
32B	8/4/1999	FGL	2120	1480	7.1	-	4.9	120	40	242	6	630	204	210	<0.4	-	<2	1.3	-	-	0.8	2.8	-	<2	-
32B	9/29/1999	FGL	1450	1010	7.2	-	3.6	88	33	156	5	362	152	210	<0.4	-	<2	0.7	-	-	0.9	3	-	<2	-

Table E-2 (continued)
Summary of Groundwater Quality Laboratory Results (Deep Zone, Composite and Lower Aquifer)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Central California ID																									
38A	10/17/2008	NA	590	-	8.1	110	-	3.5	1	120	ND	67	76	134	ND	-	-	0.17	-	-	-	-	-	ND	-
38A	7/16/2009	BSK	620	360	8.3	120	-	3.7	1.2	120	ND	63	72	120	ND	-	-	0.22	-	-	-	-	-	ND	-
38A	3/2/2012	BSK	600	350	8.2	110	-	3.8	1.2	130	ND	63	72	110	ND	-	-	0.21	-	-	-	-	-	ND	-
38A	8/9/2013	BSK	630	390	8.3	110	-	5	1.8	120	ND	71	78	163	ND	-	-	0.17	-	-	-	-	-	ND	-
38A	8/19/2014	BSK	620	390	8.1	110	-	5.5	1.7	120	ND	75	80	134	<2	-	-	0.19	-	-	-	-	-	<1	-
Columbia Canal Co.																									
MLT-W	7/21/2010	JML	540	-	8.13	-	-	2.4	0.4	143.7	-	70.6	79.8	136.7	2.9	-	-	0.272	-	-	-	-	-	-	-
MLT-W	8/9/2011	JML	550	-	8.05	-	22.3	2	-	136	-	73	70	145	ND	-	-	0.24	-	-	-	-	-	-	-
MLT-W	6/14/2012	JML	690	-	8.17	-	22.21	2.2	0.5	138	-	59	71	157	0.9	-	-	0.26	-	-	-	-	-	-	-
MLT-W	7/2/2013	JML	580	-	8.29	-	-	-	0.4	136	-	62	73.7	173	<0.2	-	-	0.16	-	-	-	-	-	-	-
Elrod-1	5/14/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
Elrod-1	7/31/2002	JML	1700	1088	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elrod-1	9/17/2003	JML(1)	1590	1020	8.1	155	15.2	34	5	361	-	160	352	-	ND	-	-	0.65	-	-	-	-	-	-	-
Elrod-1	8/4/2004	JML(1)	2730	1747	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elrod-1	8/24/2005	JML	550	-	7.55	-	7.4	18	4.3	134	-	56	79	-	0.4	-	-	0.18	-	-	-	-	-	-	-
Elrod-1	8/11/2006	JML	910	582	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elrod-1	7/31/2007	JML	1520	976	-	130	15.8	31	4.9	356	-	176	388	-	0.9	-	-	0.64	-	-	-	-	-	-	-
Elrod-1	7/16/2008	JML	2320	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elrod-1	7/21/2010	JML	1540	-	7.65	-	-	27.1	4.3	326.4	-	163.8	333.4	153.1	2.4	-	-	0.647	-	-	-	-	-	-	-
Elrod-1	8/9/2011	JML	1560	-	7.42	-	15.51	30	4	345	-	174	348	158	0.4	-	-	0.69	-	-	-	-	-	-	-
Elrod-1	6/19/2012	JML	610	-	7.99	-	10.42	10	2.4	142	-	60	79	160	1.3	-	-	0.38	-	-	-	-	-	-	-
Elrod-1	7/1/2013	JML	810	-	7.77	-	-	19	4.6	174	-	82.1	127	233	<0.2	-	-	0.28	-	-	-	-	-	-	-
Elrod-2	2/24/1999	JML	400	-	7.8	-	21.2	2	0.3	109	-	27	43	-	10.6	-	-	0.26	-	-	-	-	-	-	-
Elrod-2	5/14/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
Elrod-2	7/31/2002	JML	510	326	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elrod-2	9/17/2003	JML(1)	470	300	8.1	122	7.7	10	2	102	-	35	58	-	ND	-	-	0.25	-	-	-	-	-	-	-
Elrod-2	8/4/2004	JML(1)	1020	653	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elrod-2	8/23/2005	JML	1600	-	7.59	-	15.6	30.9	4.6	352	-	165	358	-	ND	-	-	0.62	-	-	-	-	-	-	-
Elrod-2	8/11/2006	JML	2120	1357	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elrod-2	8/1/2007	JML	550	352	-	118	10.6	9.2	1.8	134	-	66	74	-	0.4	-	-	0.38	-	-	-	-	-	-	-
Elrod-2	7/17/2008	JML	810	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elrod-2	7/21/2010	JML	670	-	7.84	-	-	15.7	3.6	151.3	-	56.2	103	176.3	1.9	-	-	0.244	-	-	-	-	-	-	-
Elrod-2	6/19/2012	JML	1370	-	7.75	-	13.76	25	5.2	292	-	152	255	171	2.7	-	-	0.6	-	-	-	-	-	-	-
Elrod-2	7/3/2013	JML	1340	-	7.73	-	-	29.3	5.5	264	-	150	340	200	2.2	-	-	0.56	-	-	-	-	-	-	-
Elrod-3	7/21/2010	JML	470	-	7.5	-	-	10.2	2.5	112.9	-	45.2	69.8	134.8	2.3	-	-	0.209	-	-	-	-	-	-	-
Elrod-3	6/19/2012	JML	520	-	7.95	-	9.98	7	1.9	116	-	44	64	137	1.3	-	-	0.22	-	-	-	-	-	-	-
Elrod-3	7/1/2013	JML	610	-	7.83	-	-	8.4	2	133	-	65.3	78	165	<0.2	-	-	0.38	-	-	-	-	-	-	-
Burkhart-Heirs	7/31/2002	JML	510	326	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Burkhart-Heirs	8/4/2004	JML(1)	880	563	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Burkhart-Heirs	8/9/2006	JML	1160	724	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Burkhart-Heirs	7/31/2007	JML	540	246	-	119	4.9	23	9.7	111	-	63	84	-	<0.4	-	-	0.22	-	-	-	-	-	-	-
Burkhart-Heirs	7/16/2008	JML	810	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Burkhart-Heirs	7/21/2010	JML	660	-	7.58	-	-	29.9	13.9	120.2	-	76.4	106	159.9	2.3	-	-	0.213	-	-	-	-	-	-	-
Burkhart-Heirs	8/9/2011	JML	680	-	7.49	-	4.71	24	11	112	-	72	91	173	ND	-	-	0.23	-	-	-	-	-	-	-
Burkhart-Heirs	6/15/2012	JML	800	-	8.13	-	4.23	37	19	126	-	98	122	179	ND	-	-	0.19	-	-	-	-	-	-	-

Table E-2 (continued)
Summary of Groundwater Quality Laboratory Results (Deep Zone, Composite and Lower Aquifer)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Columbia Canal Co.																									
Samarin-1	6/14/2012	JML	700	-	8.06	-	4.3	30	14	114	-	75	103	157	0.9	-	-	0.2	-	-	-	-	-	-	-
Samarin-1	7/2/2013	JML	650	-	7.59	-	-	21.6	10.3	108	-	66.3	95.7	181	<0.2	-	-	0.19	-	-	-	-	-	-	-
Samarin-2	8/1/2002	JML	1430	915	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Samarin-2	9/4/2003	JML(1)	930	600	7.8	143	22.1	6	1	224	-	142	139	-	ND	-	-	0.63	-	-	-	-	-	-	-
Samarin-2	8/4/2004	JML(1)	1390	890	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Samarin-2	8/23/2005	JML	930	-	7.84	-	21.5	6.6	1.1	227	-	139	145	-	ND	-	-	0.64	-	-	-	-	-	-	-
Samarin-2	8/8/2006	JML	1240	794	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Samarin-2	8/1/2007	JML	960	614	-	124	21.5	6.4	1.6	234	-	169	128	-	0.4	-	-	0.69	-	-	-	-	-	-	-
Samarin-2	7/16/2008	JML	1130	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Samarin-2	7/22/2010	JML	890	-	7.84	-	-	11	2.9	198.2	-	77.8	149.1	210.5	ND	-	-	0.209	-	-	-	-	-	-	-
Samarin-2	6/14/2012	JML	920	-	8.28	-	13.84	12	3	210	-	80	134	231	0.9	-	-	0.17	-	-	-	-	-	-	-
Samarin-2	7/2/2013	JML	940	-	7.83	-	-	12.2	3.2	205	-	80.2	153	278	<0.2	-	-	0.15	-	-	-	-	-	-	-
Samarin-3	8/1/2002	JML	1000	640	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Samarin-3	9/17/2003	JML(1)	690	440	8.0	158	9.5	14	4	158	-	70	98	-	ND	-	-	0.13	-	-	-	-	-	-	-
Samarin-3	8/4/2004	JML(1)	1170	749	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Samarin-3	8/8/2006	JML	930	595	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Samarin-3	8/1/2007	JML	640	410	-	139	9.4	13	4.4	152	-	81	78	-	0.4	-	-	0.2	-	-	-	-	-	-	-
Samarin-3	7/17/2008	JML	920	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Samarin-3	6/14/2012	JML	880	-	8.29	-	13.87	13	3	211	-	81	136	232	0.9	-	-	0.18	-	-	-	-	-	-	-
Samarin-3	7/3/2013	JML	690	-	7.92	-	-	11.4	3.8	146	-	68.7	91.1	205	<0.2	-	-	0.21	-	-	-	-	-	-	-
Samarin-4	8/6/2002	JML	750	480	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Samarin-4	9/17/2003	JML(1)	890	570	8.1	192	14	12	3	208	-	74	138	-	ND	-	-	0.15	-	-	-	-	-	-	-
Samarin-4	8/4/2004	JML	1250	800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Samarin-4	8/23/2005	JML	790	-	7.8	-	14.5	9.6	2.2	190	-	75	122	-	0.9	-	-	0.23	-	-	-	-	-	-	-
Samarin-4	8/7/2007	JML	830	534	-	169	13.9	13	2.6	208	-	80	145	-	0.4	-	-	0.23	-	-	-	-	-	-	-
Samarin-4	7/17/2008	JML	1140	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Samarin-4	7/22/2010	JML	980	-	7.85	-	-	6.5	1.3	210.3	-	139.3	170.5	147.7	ND	-	-	0.708	-	-	-	-	-	-	-
Samarin-4	6/14/2012	JML	920	-	7.95	-	20.56	6.6	1.2	218	-	131	143	153	0.9	-	-	0.73	-	-	-	-	-	-	-
Samarin-4	7/2/2013	JML	990	-	8.04	-	-	6.2	1.2	214	-	132	168	184	<0.2	-	-	0.69	-	-	-	-	-	-	-
Samarin-5	8/1/2002	JML	960	614	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Samarin-5	9/17/2003	JML(1)	660	420	8.2	144	6.5	19	8	134	-	66	90	-	ND	-	-	0.28	-	-	-	-	-	-	-
Samarin-5	8/4/2004	JML(1)	1010	646	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Samarin-5	8/23/2005	JML	600	-	7.46	-	6.6	16.4	7.2	127	-	68	83	-	0.9	-	-	0.27	-	-	-	-	-	-	-
Samarin-5	8/9/2006	JML	860	550	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Samarin-5	8/1/2007	JML	640	410	-	136	5.8	22	10	131	-	84	62	-	0.4	-	-	0.25	-	-	-	-	-	-	-
Samarin-5	7/17/2008	JML	820	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Samarin-5	7/22/2010	JML	640	-	7.89	-	-	2.8	0.5	150.1	-	73	96.5	137.3	ND	-	-	0.311	-	-	-	-	-	-	-
Snyder	5/4/2001	JML	950	608	7.9	-	9	20	3	164	-	123	147	-	4.4	-	-	0.5	-	-	-	-	-	-	-
Snyder	7/31/2002	JML	660	420	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snyder	9/9/2003	JML(1)	650	420	8.1	146	21.3	3	1	166	-	80	85	-	ND	-	-	0.22	-	-	-	-	-	-	-
Snyder	8/4/2004	JML(1)	1060	678	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snyder	8/26/2005	JML	710	-	7.89	-	19.7	3.6	1.1	166	-	92	95	-	ND	-	-	0.14	-	-	-	-	-	-	-
Snyder	8/11/2006	JML	990	634	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snyder	8/1/2007	JML	680	435	-	124	69	0.2	0.2	177	-	90	77	-	0.4	-	-	0.23	-	-	-	-	-	-	-
Snyder	7/16/2008	JML	890	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table E-2 (continued)
Summary of Groundwater Quality Laboratory Results (Deep Zone, Composite and Lower Aquifer)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Wonderful Orchards																									
3591-66 (W-11)	9/22/2011	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3591-66 (W-11)	8/24/2012	JML	850	-	7.78	-	-	-	-	94	-	-	38	354	27	-	-	0.04	-	-	-	-	-	-	-
3591-66 (W-11)	8/24/2012	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3591-66 (W-11)	8/5/2013	JML	870	-	7.64	-	-	80	18	88.5	-	-	44.7	390	23.5	-	-	0.06	-	-	-	-	-	-	-
3591-66 (W-11)	8/5/2013	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3591-66 (W-11)	6/26/2014	FGL	938	-	7.74	-	-	88	18	96	5.2	88	56	349	29.2	0.06	-	0.076	-	0.011	0.091	ND	-	-	0.019
3591-66 (W-11)	8/5/2014	JML	960	-	7.96	-	-	-	-	108	-	-	66	390	32.3	-	-	0.08	-	-	-	-	-	-	-
3591-66 (W-11)	8/5/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3311-63 (W-12)	6/20/2014	FGL	906	-	7.39	-	-	69	17	116	2.6	91	54	323	52.1	0.06	-	0.025	-	0.01	0.061	ND	-	-	0.011
3211-66 (W-15)	8/22/2007	JML	770	-	-	219	9.3	18	5	178	-	86	68	-	8	-	-	0.1	-	-	-	-	-	<1	-
3211-66 (W-15)	9/18/2008	JML	750	-	7.9	-	7.8	-	-	163	-	-	71	262	9.7	-	-	0.11	-	-	-	-	-	<1	-
3211-66 (W-15)	9/10/2009	JML	730	-	7.8	-	7.6	-	-	155	-	-	67	148	10.6	-	-	0.12	-	-	-	-	-	-	-
3211-66 (W-15)	9/10/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3211-66 (W-15)	8/17/2010	JML	720	-	7.8	-	7.27	-	-	159	-	-	71	245	13.7	-	-	0.15	-	-	-	-	-	-	-
3211-66 (W-15)	8/17/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3211-66 (W-15)	9/22/2011	JML	740	-	7.51	-	7.28	-	-	155	-	-	69.8	231	12.4	-	-	0.13	-	-	-	-	-	-	-
3211-66 (W-15)	9/22/2011	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3211-66 (W-15)	8/27/2012	JML	770	-	8.15	-	-	-	-	145	-	-	69	240	13.7	-	-	0.14	-	-	-	-	-	-	-
3211-66 (W-15)	8/27/2012	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3211-66 (W-15)	8/7/2013	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3211-66 (W-15)	8/7/2013	JML	750	-	7.85	-	-	24	7.5	143	-	-	77.3	267	12	-	-	0.15	-	-	-	-	-	-	-
3211-66 (W-15)	6/24/2014	FGL	751	-	8.08	-	-	24	6.5	135	3.8	69	68	228	10.7	0.06	-	0.156	-	0.003	0.082	0.254	-	-	0.021
3211-66 (W-15)	8/5/2014	JML	780	-	8.17	-	-	-	-	154	-	-	82	260	14.6	-	-	0.15	-	-	-	-	-	-	-
3211-66 (W-15)	8/5/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3431-61 (W-32)	8/28/1953	AT	-	277	8.1	-	6.2	6	3.5	77	-	4.1	39	168	-	-	-	0.04	-	-	-	-	-	-	-
3431-61 (W-32)	5/18/1979	AT	600	380	7.9	-	-	-	-	106	-	-	43	275	-	-	-	0.3	-	-	-	-	-	-	-
3431-61 (W-32)	8/4/1979	AT	680	440	8.0	-	-	-	-	124	-	-	60	287	-	-	-	0.5	-	-	-	-	-	-	-
3431-61 (W-32)	11/8/1994	JML	970	-	7.8	-	4.7	-	-	154	-	-	99	262	28	-	-	0.29	-	-	-	-	-	<0.5	-
3431-61 (W-32)	4/3/1995	JML	980	-	8.2	-	4.7	-	-	152	-	-	99	275	28	-	-	0.29	-	-	-	-	-	<0.5	-
3431-61 (W-32)	9/15/1995	JML	1080	-	8.0	-	6.7	-	-	184	-	-	99	366	27	-	-	0.43	-	-	-	-	-	0.59	-
3431-61 (W-32)	3/19/1996	JML	1020	-	7.9	-	5.9	-	-	163	-	-	96	384	28	-	-	0.33	-	-	-	-	-	<0.5	-
3431-61 (W-32)	9/4/1996	JML	1100	-	7.8	-	5.8	-	-	159	-	-	121	305	30	-	-	0.3	-	-	-	-	-	<0.5	-
3431-61 (W-32)	4/4/1997	JML	1100	-	8.0	-	4.6	-	-	149	-	-	96	165	44	-	-	0.3	-	-	-	-	-	<0.5	-
3431-61 (W-32)	7/2/1997	JML	1100	-	8.6	-	6.6	-	-	182	-	-	82	574	54	-	-	0.3	-	-	-	-	-	-	-
3431-61 (W-32)	4/17/2001	JML	1100	-	7.7	-	6.4	-	-	198	-	-	124	366	56	-	-	0.3	-	-	-	-	-	ND	-
3431-61 (W-32)	9/14/2001	JML	1210	-	7.3	-	4.8	-	-	184	-	-	117	421	53	-	-	0.22	-	-	-	-	-	0.73	-
3431-61 (W-32)	3/13/2002	JML	1120	-	7.9	-	5.6	-	-	195	-	-	124	384	9	-	-	0.3	-	-	-	-	-	<0.5	-
3431-61 (W-32)	8/15/2002	JML	830	-	8.0	-	10.6	-	-	191	-	-	64	293	2	-	-	0.1	-	-	-	-	-	<0.5	-
3431-61 (W-32)	8/14/2003	JML	1000	800	7.8	-	-	-	-	210	-	-	121	378	8.2	-	-	0.34	-	-	-	-	-	<0.4	-
3431-61 (W-32)	8/12/2004	JML	1820	1165	7.6	-	6	-	-	205	-	-	121	348	45	-	-	0.38	-	-	-	-	-	<0.4	-
3431-61 (W-32)	3/11/2005	JML	1800	-	7.6	-	6.6	-	-	214	-	-	128	354	39	-	-	0.36	-	-	-	-	-	<0.4	-
3431-61 (W-32)	9/9/2005	JML	1710	-	7.5	-	6.1	-	-	209	-	-	124	366	47.8	-	-	0.31	-	-	-	-	-	<0.4	-
3431-61 (W-32)	9/18/2006	JML	1110	710.4	7.5	-	-	-	-	214	-	-	103	378	42.1	-	-	0.4	-	-	-	-	-	<1	-
3431-61 (W-32)	4/19/2007	JML	1240	-	-	313	5.2	86	19	203	-	132	121	-	66.4	-	-	0.27	-	-	-	-	-	-	-
3431-61 (W-32)	8/20/2007	JML	1200	-	-	295	5.6	75	17	205	-	121	126	-	57.6	-	-	0.28	-	-	-	-	-	<1	-
3431-61 (W-32)	9/11/2008	JML	1140	-	7.7	-	5.5	-	-	200	-	-	131	384	56.7	-	-	0.32	-	-	-	-	-	<1	-

Table E-2 (continued)
Summary of Groundwater Quality Laboratory Results (Deep Zone, Composite and Lower Aquifer)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab [1]	EC [2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity [3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3 [3] (mg/L)	NO_3 [3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Wonderful Orchards																									
3730-65 (W-53)	4/3/1995	JML	550	-	8.3	-	3.9	-	-	85	-	-	71	122	4	-	-	0.06	-	-	-	-	-	-	-
3730-65 (W-53)	9/15/1995	JML	540	-	8.3	-	5.2	-	-	92	-	-	39	140	7	-	-	0.06	-	-	-	-	-	-	-
3730-65 (W-53)	3/19/1996	JML	570	-	8.4	-	4.4	-	-	92	-	-	78	244	2	-	-	0.1	-	-	-	-	-	<0.5	-
3730-65 (W-53)	9/4/1996	JML	600	-	8.2	-	5.2	-	-	83	-	-	82	92	2	-	-	0.1	-	-	-	-	-	<0.5	-
3730-65 (W-53)	4/4/1997	JML	600	-	8.3	-	3.5	-	-	78	-	-	74	55	4	-	-	0.2	-	-	-	-	-	<0.5	-
3730-65 (W-53)	7/2/1997	JML	600	-	8.3	-	6.5	-	-	108	-	-	64	177	14	-	-	0.1	-	-	-	-	-	<0.8	-
3730-65 (W-53)	9/1/1997	BSK	500	-	8.2	-	-	-	-	-	-	97	57	110	4	-	-	0.1	-	-	-	-	-	-	-
3730-65 (W-53)	3/1/1998	BSK	565	-	8.3	-	-	-	-	21	1	97	83	-	<2	-	-	0.1	-	-	-	-	-	<0.5	-
3730-65 (W-53)	9/1/1998	BSK	610	-	8.3	-	-	-	-	-	-	97	64	-	3	-	-	0.1	-	-	-	-	-	<0.5	-
3730-65 (W-53)	3/1/1999	BSK	570	-	8.1	-	-	-	-	-	-	122	57	134	6	-	-	0.1	-	-	-	-	-	<0.5	-
3730-65 (W-53)	9/1/1999	BSK	600	-	8.2	-	-	-	-	-	-	110	71	153	3	-	-	0.1	-	-	-	-	-	1.2	-
3730-65 (W-53)	3/21/2000	JML	530	-	8.1	122	6.4	22	2	117	-	56	105	-	2	-	-	0.03	-	-	-	-	-	<0.4	-
3730-65 (W-53)	10/3/2000	JML	520	-	8.2	121	5.5	27	2	110	-	54	71	-	-	-	-	0.08	-	-	-	-	-	<0.4	-
3730-65 (W-53)	3/21/2001	JML	540	-	8.2	115	5.6	19	3	99	-	49	75	-	-	-	-	0.07	-	-	-	-	-	<0.4	-
3730-65 (W-53)	6/26/2001	JML	530	-	8.3	120	6.6	18	ND	102	-	49	78	-	-	-	-	0.08	-	-	-	-	-	-	-
3730-65 (W-53)	9/14/2001	JML	580	-	8.1	-	5.5	-	-	97	-	-	71	262	ND	-	-	0.07	-	-	-	-	-	ND	-
3730-65 (W-53)	3/13/2002	JML	520	-	8.1	-	5.6	-	-	101	-	-	74	153	-	-	-	0.1	-	-	-	-	-	<0.5	-
3730-65 (W-53)	8/15/2002	JML	1200	-	7.6	-	10.1	-	-	262	-	-	145	354	6	-	-	0.4	-	-	-	-	-	<0.5	-
3730-65 (W-53)	7/15/2003	JML(1)	550	350	8.3	141	5.8	23	3	112	-	52	67	-	ND	-	-	0.13	-	-	-	-	-	-	-
3730-65 (W-53)	8/14/2003	JML	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
3730-65 (W-53)	8/17/2004	JML	560	352	8.3	-	5.4	-	-	99	-	-	53	140	0.9	-	-	0.09	-	-	-	-	-	<0.4	-
3730-65 (W-53)	3/11/2005	JML	850	-	8.1	-	5.2	-	-	101	-	-	64	146	ND	-	-	0.11	-	-	-	-	-	<0.4	-
3730-65 (W-53)	9/9/2005	JML	710	-	8.0	-	5.4	-	-	99	-	-	64	146	ND	-	-	0.1	-	-	-	-	-	<0.4	-
3730-65 (W-53)	7/19/2006	JML	840	538	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3730-65 (W-53)	9/18/2006	JML	480	307.2	8.2	-	-	-	-	99	-	-	57	146	1.3	-	-	0.1	-	-	-	-	-	<1	-
3730-65 (W-53)	4/19/2007	JML	480	-	-	107	5.3	22	3	100	-	50	63	-	30.1	-	-	0.11	-	-	-	-	-	-	-
3730-65 (W-53)	8/20/2007	JML	480	-	-	110	5.3	20	3	96	-	47	61	-	<0.4	-	-	0.1	-	-	-	-	-	<1	-
3730-65 (W-53)	9/11/2008	JML	410	-	8.3	-	5.8	-	-	92	-	-	57	128	ND	-	-	0.16	-	-	-	-	-	<1	-
3730-65 (W-53)	9/10/2009	JML	430	-	8.3	-	5.9	-	-	93	-	-	54	121	0.4	-	-	0.13	-	-	-	-	-	-	-
3730-65 (W-53)	9/10/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-65 (W-53)	8/9/2010	JML	410	-	8.0	-	6.47	-	-	90	-	-	47	120	3.1	-	-	0.19	-	-	-	-	-	-	-
3730-65 (W-53)	8/9/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-65 (W-53)	9/22/2011	JML	470	-	7.73	-	5.48	-	-	86.9	-	-	53.9	123	ND	-	-	0.15	-	-	-	-	-	-	-
3730-65 (W-53)	9/22/2011	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-65 (W-53)	8/24/2012	JML	430	-	8.32	-	-	-	-	92	-	-	51	121	ND	-	-	0.15	-	-	-	-	-	-	-
3730-65 (W-53)	8/24/2012	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-65 (W-53)	8/5/2013	JML	510	-	8.22	-	-	18	2.7	93.3	-	-	63.8	154	<0.2	-	-	0.1	-	-	-	-	-	-	-
3730-65 (W-53)	8/5/2013	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-65 (W-53)	6/16/2014	FGL	451	-	8.35	-	-	14	1.7	79	2.3	28	51	116	<0.4	0.24	-	0.148	-	0.016	0.106	0.063	-	-	0.027
3730-65 (W-53)	8/5/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-65 (W-53)	8/5/2014	JML	550	-	8.39	-	-	-	-	99	-	-	76	153	<0.1	-	-	0.13	-	-	-	-	-	-	-
3421-62 (W-74)	1/27/1975	TL	-	684	8.1	-	20	7	1	214	-	124	156	168	-	-	-	0.3	-	-	-	-	-	-	-
3421-62 (W-74)	11/8/1994	JML	1000	-	8.1	-	11.4	-	-	177	-	-	152	122	4	-	-	0.61	-	-	-	-	-	<0.5	-
3421-62 (W-74)	4/3/1995	JML	1020	-	8.0	-	11.9	-	-	193	-	-	145	153	4	-	-	0.78	-	-	-	-	-	ND	-
3421-62 (W-74)	9/15/1995	JML	1090	-	8.2	-	23.9	-	-	223	-	-	163	140	2	-	-	0.75	-	-	-	-	-	<0.5	-
3421-62 (W-74)	3/19/1996	JML	980	-	8.2	-	13.9	-	-	202	-	-	138	244	4	-	-	0.84	-	-	-	-	-	<0.5	-
3421-62 (W-74)	9/4/1996	JML	1000	-	8.0	-	36.7	-	-	189	-	-	149	122	3	-	-	0.6	-	-	-	-	-	<0.5	-

Table E-2 (continued)
Summary of Groundwater Quality Laboratory Results (Deep Zone, Composite and Lower Aquifer)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Wonderful Orchards																									
3211-69 (W-77)	9/10/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3211-69 (W-77)	9/10/2009	JML	890	-	7.7	-	11.9	-	-	204	-	-	84	303	9.7	-	-	0.16	-	-	-	-	-	-	-
3211-69 (W-77)	8/17/2010	JML	820	-	7.8	-	12.59	-	-	204	-	-	106	260	8.4	-	-	0.3	-	-	-	-	-	-	-
3211-69 (W-77)	8/17/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3211-69 (W-77)	9/22/2011	JML	840	-	7.75	-	12.17	-	-	197	-	-	100	234	7.1	-	-	0.29	-	-	-	-	-	-	-
3211-69 (W-77)	9/22/2011	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3211-69 (W-77)	8/27/2012	JML	930	-	8.11	-	-	-	-	197	-	-	103	272	8	-	-	0.27	-	-	-	-	-	-	-
3211-69 (W-77)	8/27/2012	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3211-69 (W-77)	8/5/2013	JML	920	-	7.93	-	-	14.2	4.3	200	-	-	105	320	8.9	-	-	0.22	-	-	-	-	-	-	-
3211-69 (W-77)	8/5/2013	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3211-69 (W-77)	6/26/2014	FGL	978	-	8.11	-	-	19	4.9	204	4.8	98	96	287	11.5	0.2	-	0.209	-	ND	0.087	0.092	-	-	0.011
3211-69 (W-77)	8/5/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3211-69 (W-77)	8/5/2014	JML	1050	-	8.17	-	-	-	-	229	-	-	115	355	17.7	-	-	0.17	-	-	-	-	-	-	-
2630-61 (W-78)	4/13/1976	TL	-	314	8.0	-	12.9	2	2	108	-	42	64	137	1	-	-	0.6	-	-	-	-	-	-	-
2630-61 (W-78)	7/21/1977	TL	337	-	8.4	-	11.4	2	1	79	-	39	35	64	1	-	-	0.3	-	-	-	-	-	-	-
2630-61 (W-78)	11/8/1994	JML	430	-	8.6	-	8.4	-	-	87	-	-	57	110	4	-	-	0.22	-	-	-	-	-	<0.5	-
2630-61 (W-78)	4/3/1995	JML	360	-	8.6	-	ND	-	-	78	-	-	53	92	3	-	-	0.2	-	-	-	-	-	ND	-
2630-61 (W-78)	9/15/1995	JML	390	-	8.3	-	19.8	-	-	85	-	-	21	122	8	-	-	0.15	-	-	-	-	-	0.54	-
2630-61 (W-78)	3/19/1996	JML	390	-	8.7	-	7.8	-	-	87	-	-	53	122	2	-	-	0.16	-	-	-	-	-	<0.5	-
2630-61 (W-78)	9/4/1996	JML	500	-	8.6	-	24.7	-	-	85	-	-	43	85	2	-	-	0.2	-	-	-	-	-	<0.5	-
2630-61 (W-78)	4/4/1997	JML	400	-	8.5	-	5.9	-	-	74	-	-	39	37	3	-	-	0.2	-	-	-	-	-	ND	-
2630-61 (W-78)	7/2/1997	JML	400	-	8.4	-	46	-	-	106	-	-	43	177	14	-	-	0.1	-	-	-	-	-	<0.8	-
2630-61 (W-78)	9/1/1997	JML	400	-	8.5	-	-	-	-	94	-	-	32	110	8	-	-	0.1	-	-	-	-	-	<2	-
2630-61 (W-78)	3/1/1998	JML	396	-	8.5	-	-	<1	<1	88	-	-	75	-	<2	-	-	0.1	-	-	-	-	-	<0.5	-
2630-61 (W-78)	9/1/1998	JML	480	-	8.5	-	-	-	-	94	-	-	39	-	5	-	-	0.2	-	-	-	-	-	<0.5	-
2630-61 (W-78)	3/1/1999	JML	410	-	8.5	-	-	-	-	120	-	-	43	122	11	-	-	0.2	-	-	-	-	-	<0.5	-
2630-61 (W-78)	9/1/1999	JML	500	-	8.2	-	-	-	-	117	-	-	46	146	3	-	-	0.2	-	-	-	-	-	1.4	-
2630-61 (W-78)	3/21/2000	JML	400	-	8.5	113	13.9	3	<1	109	-	38	58	-	3	-	-	0.05	-	-	-	-	-	<0.4	-
2630-61 (W-78)	10/3/2000	JML	450	-	8.3	116	11.3	7	<1	121	-	51	55	-	-	-	-	0.15	-	-	-	-	-	<0.4	-
2630-61 (W-78)	3/21/2001	JML	450	-	7.4	109	16.8	1	<1	99	-	44	54	-	-	-	-	0.13	-	-	-	-	-	<0.4	-
2630-61 (W-78)	6/26/2001	JML	400	-	8.5	112	16.4	1	ND	97	-	32	50	-	-	-	-	0.09	-	-	-	-	-	-	-
2630-61 (W-78)	9/14/2001	JML	430	-	8.3	-	29.2	-	-	94	-	-	46	140	ND	-	-	0.1	-	-	-	-	-	ND	-
2630-61 (W-78)	3/13/2002	JML	440	-	8.2	-	37.5	-	-	106	-	-	57	140	-	-	-	0.1	-	-	-	-	-	<0.5	-
2630-61 (W-78)	8/15/2002	JML	1000	-	7.9	-	23.4	-	-	232	-	-	138	165	-	-	-	0.6	-	-	-	-	-	<0.5	-
2630-61 (W-78)	6/20/2003	JML	560	-	8.3	-	-	-	-	101	-	-	46	157	ND	-	-	0.13	-	-	-	-	-	-	-
2630-61 (W-78)	8/14/2003	JML	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
2630-61 (W-78)	8/12/2004	JML	400	256	8.4	-	81.6	-	-	101	-	-	32	122	ND	-	-	0.14	-	-	-	-	-	<0.4	-
2630-61 (W-78)	3/11/2005	JML	570	-	8.3	-	24.2	-	-	92	-	-	43	110	ND	-	-	0.13	-	-	-	-	-	<0.4	-
2630-61 (W-78)	9/9/2005	JML	550	-	8.2	-	66.9	-	-	97	-	-	43	122	ND	-	-	0.12	-	-	-	-	-	<0.4	-
2630-61 (W-78)	7/20/2006	JML	960	614	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2630-61 (W-78)	9/18/2006	JML	370	236.8	8.4	-	-	-	-	99	-	-	35	122	0.4	-	-	0.1	-	-	-	-	-	<1	-
2630-61 (W-78)	4/19/2007	JML	390	-	-	94	22.6	1	0.24	103	-	45	51	-	0.4	-	-	0.13	-	-	-	-	-	-	-
2630-61 (W-78)	8/20/2007	JML	420	-	-	104	20.7	1	0.36	110	-	43	51	-	0.4	-	-	0.12	-	-	-	-	-	<1	-
2630-61 (W-78)	9/11/2008	JML	420	-	8.4	-	19	-	-	110	-	-	64	128	ND	-	-	0.18	-	-	-	-	-	<1	-
2630-61 (W-78)	9/10/2009	JML	420	-	8.1	-	21.4	-	-	107	-	-	51	126	0.4	-	-	0.15	-	-	-	-	-	-	-
2630-61 (W-78)	9/10/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
2630-61 (W-78)	8/9/2010	JML	430	-	8.1	-	29.61	-	-	113	-	-	50	124	2.7	-	-	0.21	-	-	-	-	-	-	-

Table E-2 (continued)
Summary of Groundwater Quality Laboratory Results (Deep Zone, Composite and Lower Aquifer)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Wonderful Orchards																									
3431-62 (W-91)	3/21/2001	JML	1000	-	7.7	-	6.9	-	-	172	-	-	110	360	46	-	-	0.18	-	-	-	-	-	ND	-
3431-62 (W-91)	9/14/2001	JML	1020	-	7.7	-	6.1	-	-	175	-	-	106	348	31	-	-	0.19	-	-	-	-	-	ND	-
3431-62 (W-91)	3/13/2002	JML	1000	-	7.8	-	6.4	-	-	189	-	-	117	366	7	-	-	0.2	-	-	-	-	-	<0.5	-
3431-62 (W-91)	8/15/2002	JML	420	-	8.3	-	28.4	-	-	113	-	-	50	128	-	-	-	0.1	-	-	-	-	-	0.4	-
3431-62 (W-91)	8/14/2003	JML	1100	-	7.3	-	-	-	-	188	-	-	111	426	7.6	-	-	0.24	-	-	-	-	-	<0.4	-
3431-62 (W-91)	8/12/2004	JML	1660	1062	7.3	-	6.3	-	-	228	-	-	142	354	34	-	-	0.26	-	-	-	-	-	<0.4	-
3431-62 (W-91)	3/11/2005	JML	1740	-	7.5	-	6.8	-	-	205	-	-	113	360	32.8	-	-	0.24	-	-	-	-	-	0.5	-
3431-62 (W-91)	9/9/2005	JML	1500	-	7.5	-	7.9	-	-	218	-	-	124	366	34.5	-	-	0.23	-	-	-	-	-	<0.4	-
3431-62 (W-91)	9/18/2006	JML	1340	857.6	7.6	-	-	-	-	280	-	-	230	372	28.3	-	-	0.2	-	-	-	-	-	<1	-
3431-62 (W-91)	4/19/2007	JML	1030	-	-	280	6.6	52	10	199	-	81	111	-	33.6	-	-	0.23	-	-	-	-	-	-	-
3431-62 (W-91)	8/27/2007	JML	1000	-	-	281	7.2	51	10	214	-	171	119	-	36.7	-	-	0.26	-	-	-	-	-	<1	-
3431-62 (W-91)	9/11/2008	JML	1010	-	7.6	-	6.7	-	-	198	-	-	117	348	38.1	-	-	0.26	-	-	-	-	-	<1	-
3431-62 (W-91)	9/10/2009	JML	990	-	7.7	-	6.9	-	-	201	-	-	115	337	41.2	-	-	0.27	-	-	-	-	-	-	-
3431-62 (W-91)	9/10/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3431-62 (W-91)	8/17/2010	JML	830	-	7.5	-	6.94	-	-	211	-	-	122	329	42.1	-	-	0.29	-	-	-	-	-	-	-
3431-62 (W-91)	8/17/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3431-62 (W-91)	9/22/2011	JML	1020	-	7.63	-	6.62	-	-	194	-	-	122	290	35.9	-	-	0.28	-	-	-	-	-	-	-
3431-62 (W-91)	9/22/2011	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3431-62 (W-91)	8/27/2012	JML	1060	-	7.96	-	-	-	-	190	-	-	121	329	31.4	-	-	0.28	-	-	-	-	-	-	-
3431-62 (W-91)	8/27/2012	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3431-62 (W-91)	8/5/2013	JML	1060	-	7.72	-	-	39	8.6	191	-	-	136	367	27	-	-	0.26	-	-	-	-	-	-	-
3431-62 (W-91)	8/5/2013	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3431-62 (W-91)	6/23/2014	FGL	1088	-	7.49	-	-	45	8.4	187	5.3	74	128	310	30.1	0.06	-	0.311	-	0.01	0.075	ND	-	-	0.026
3431-62 (W-91)	8/5/2014	JML	1090	-	7.96	-	-	-	-	200	-	-	151	347	33.2	-	-	0.31	-	-	-	-	-	-	-
3431-62 (W-91)	8/5/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-62 (W-94)	11/8/1994	JML	480	-	8.8	-	8.3	-	-	85	-	-	64	110	3	-	-	0.3	-	-	-	-	-	0.23	-
3730-62 (W-94)	4/3/1995	JML	390	-	8.8	-	7.7	-	-	78	-	-	35	92	4	-	-	0.19	-	-	-	-	-	0.11	-
3730-62 (W-94)	9/15/1995	JML	650	-	8.6	-	6.5	-	-	110	-	-	64	171	1	-	-	0.3	-	-	-	-	-	0.33	-
3730-62 (W-94)	3/19/1996	JML	500	-	8.8	-	9	-	-	106	-	-	64	110	2	-	-	0.32	-	-	-	-	-	0.11	-
3730-62 (W-94)	9/4/1996	JML	500	-	8.7	-	-	ND	ND	94	-	-	57	79	6	-	-	0.3	-	-	-	-	-	0.02	-
3730-62 (W-94)	4/4/1997	JML	500	-	8.6	-	1.7	-	-	90	-	-	53	43	4	-	-	0.3	-	-	-	-	-	ND	-
3730-62 (W-94)	7/2/1997	JML	400	-	8.5	-	30.1	-	-	108	-	-	43	177	19	-	-	0.2	-	-	-	-	-	<0.8	-
3730-62 (W-94)	9/1/1997	JML	400	-	8.6	-	-	-	-	92	-	-	32	110	11	-	-	0.2	-	-	-	-	-	<2	-
3730-62 (W-94)	3/1/1998	JML	403	-	8.3	-	-	<1	<1	92	-	-	59	-	ND	-	-	0.2	-	-	-	-	-	<0.5	-
3730-62 (W-94)	9/1/1998	JML	450	-	8.6	-	-	-	-	92	-	-	35	-	11	-	-	0.2	-	-	-	-	-	<0.5	-
3730-62 (W-94)	3/1/1999	JML	380	-	8.6	-	-	-	-	113	-	-	32	134	14	-	-	0.2	-	-	-	-	-	<0.5	-
3730-62 (W-94)	9/1/1999	JML	440	-	8.5	-	-	-	-	108	-	-	35	159	2	-	-	0.2	-	-	-	-	-	1.3	-
3730-62 (W-94)	3/21/2000	JML	410	-	8.6	123	17.7	2	<1	123	-	40	21	-	3	-	-	0.14	-	-	-	-	-	<0.4	-
3730-62 (W-94)	10/3/2000	JML	410	-	8.5	129	10.4	7	<1	111	-	39	39	-	-	-	-	0.14	-	-	-	-	-	<0.4	-
3730-62 (W-94)	3/29/2001	JML	400	-	8.8	-	14.5	-	-	97	-	-	35	146	ND	-	-	0.12	-	-	-	-	-	ND	-
3730-62 (W-94)	6/22/2001	JML	450	-	8.5	145	33	1	ND	120	-	37	48	-	-	-	-	0.07	-	-	-	-	-	-	-
3730-62 (W-94)	9/14/2001	JML	380	-	8.5	-	24.3	-	-	87	-	-	35	153	ND	-	-	0.14	-	-	-	-	-	ND	-
3730-62 (W-94)	3/13/2002	JML	390	-	8.4	-	34.1	-	-	97	-	-	39	165	-	-	-	0.2	-	-	-	-	-	<0.5	-
3730-62 (W-94)	8/15/2002	JML	1110	-	7.8	-	6.6	-	-	214	-	-	82	391	6	-	-	0.2	-	-	-	-	-	<0.5	-
3730-62 (W-94)	7/2/2003	JML(1)	350	220	8.6	141	31.3	1	ND	106	-	42	47	-	ND	-	-	0.2	-	-	-	-	-	-	-
3730-62 (W-94)	8/14/2003	JML	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
3730-62 (W-94)	8/12/2004	JML	700	448	8.6	-	36.7	-	-	115	-	-	53	153	0.9	-	-	0.26	-	-	-	-	-	<0.4	-

Table E-2 (continued)
Summary of Groundwater Quality Laboratory Results (Deep Zone, Composite and Lower Aquifer)

Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Cations				Anions					Trace Elements								
								Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Wonderful Orchards																									
3730-61 (W-95)	8/24/2012	JML	360	-	8.61	-	-	-	-	91	-	-	27	130	ND	-	-	0.09	-	-	-	-	-	-	-
3730-61 (W-95)	8/24/2012	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-61 (W-95)	8/5/2013	JML	380	-	8.56	-	-	1	0.24	92.2	-	-	30.1	163	<0.2	-	-	0.12	-	-	-	-	-	-	-
3730-61 (W-95)	8/5/2013	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-61 (W-95)	6/19/2014	FGL	366	-	8.23	-	-	1.2	0.19	79	1.1	23	28	115	<0.4	0.19	-	ND	-	0.004	0.106	0.008	-	-	0.007
3730-61 (W-95)	8/5/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-61 (W-95)	8/5/2014	JML	370	-	8.73	-	-	-	-	93	-	-	28	149	<0.1	-	-	0.13	-	-	-	-	-	-	-
3921-61 (W-106)	9/10/2009	JML	580	-	8.3	-	23.6	-	-	141	-	-	75	136	-	-	-	0.1	-	-	-	-	-	-	-
3921-61 (W-106)	9/10/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3921-61 (W-106)	8/17/2010	JML	520	-	8.3	-	27.44	-	-	137	-	-	74	135	ND	-	-	0.09	-	-	-	-	-	-	-
3921-61 (W-106)	8/17/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3921-61 (W-106)	9/22/2011	JML	510	-	7.97	-	26.32	-	-	126	-	-	67.7	138	0.4	-	-	0.09	-	-	-	-	-	-	-
3921-61 (W-106)	9/22/2011	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3921-61 (W-106)	8/24/2012	JML	560	-	8.33	-	-	-	-	137	-	-	68	138	ND	-	-	0.27	-	-	-	-	-	-	-
3921-61 (W-106)	8/24/2012	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3921-61 (W-106)	8/5/2013	JML	560	-	8.32	-	-	1.4	0.24	132	-	-	68.4	171	<0.2	-	-	0.26	-	-	-	-	-	-	-
3921-61 (W-106)	8/5/2013	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3921-61 (W-106)	8/5/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3921-61 (W-106)	8/5/2014	JML	580	-	8.43	-	-	-	-	141	-	-	78	159	<0.1	-	-	0.32	-	-	-	-	-	-	-
3730-72 (W-107)	9/10/2009	JML	520	-	8.1	-	17.1	-	-	126	-	-	62	143	-	-	-	0.2	-	-	-	-	-	-	-
3730-72 (W-107)	9/10/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-72 (W-107)	8/9/2010	JML	510	-	8.0	-	17.94	-	-	129	-	-	59	144	3.1	-	-	0.23	-	-	-	-	-	-	-
3730-72 (W-107)	8/9/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-72 (W-107)	9/22/2011	JML	510	-	7.76	-	18.29	-	-	124	-	-	62.4	653	0.4	-	-	0.25	-	-	-	-	-	-	-
3730-72 (W-107)	9/22/2011	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-72 (W-107)	8/24/2012	JML	540	-	8.18	-	-	-	-	138	-	-	65	150	ND	-	-	0.27	-	-	-	-	-	-	-
3730-72 (W-107)	8/24/2012	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-72 (W-107)	8/5/2013	JML	580	-	8.19	-	-	2.2	0.61	135	-	-	71.3	173	<0.2	-	-	0.26	-	-	-	-	-	-	-
3730-72 (W-107)	8/5/2013	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-72 (W-107)	6/16/2014	FGL	597	-	8.33	-	-	2.6	0.56	126	1.5	46	69	144	<0.4	0.46	-	0.264	-	0.035	0.292	0.051	-	-	0.051
3730-72 (W-107)	8/5/2014	JML	570	-	8.39	-	-	-	-	141	-	-	74	175	<0.1	-	-	0.27	-	-	-	-	-	-	-
3730-72 (W-107)	8/5/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-70 (W-108)	9/10/2009	JML	530	-	8.1	-	19.3	-	-	128	-	-	68	146	0.4	-	-	0.27	-	-	-	-	-	-	-
3730-70 (W-108)	9/10/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-70 (W-108)	8/9/2010	JML	550	-	8.0	-	19.77	-	-	139	-	-	79	138	3.1	-	-	0.35	-	-	-	-	-	-	-
3730-70 (W-108)	8/9/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-70 (W-108)	9/22/2011	JML	560	-	7.75	-	20.22	-	-	137	-	-	76.9	159	ND	-	-	0.36	-	-	-	-	-	-	-
3730-70 (W-108)	9/22/2011	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-70 (W-108)	8/24/2012	JML	600	-	8.26	-	-	-	-	149	-	-	79	145	ND	-	-	0.35	-	-	-	-	-	-	-
3730-70 (W-108)	8/24/2012	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-70 (W-108)	8/5/2013	JML	610	-	8.24	-	-	2.2	0.49	140	-	-	82.6	167	<0.2	-	-	0.31	-	-	-	-	-	-	-
3730-70 (W-108)	8/5/2013	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3730-70 (W-108)	6/16/2014	FGL	607	-	8.38	-	-	2.4	0.39	126	1.9	50	76	127	<0.4	0.49	-	0.318	-	0.005	0.11	0.053	-	-	0.015
3730-70 (W-108)	8/5/2014	JML	620	-	8.4	-	-	-	-	148	-	-	92	158	<0.1	-	-	0.37	-	-	-	-	-	-	-
3730-70 (W-108)	8/5/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
3211-68 (W-110)	9/10/2009	JML	630	-	8.1	-	21.5	-	-	153	-	-	76	181	0.4	-	-	0.21	-	-	-	-	-	-	-

Table E-2 (continued)
Summary of Groundwater Quality Laboratory Results (Deep Zone, Composite and Lower Aquifer)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Wonderful Orchards																									
3730-92 (MW-1)	8/5/2014	JML	700	-	7.76	-	-	-	-	96	-	-	94	120	<0.1	-	-	0.2	-	-	-	-	-	-	-
3730-92 (MW-1)	8/5/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
2480-92 (MW-7)	11/16/2006	BSK	1600	1100	8.0	360	-	120	26	240	7.9	130	230	440	40	-	-	0.18	-	-	<0.05	0.078	-	-	-
2480-92 (MW-7)	11/29/2011	DL	1400	-	8.2	245	-	54	12.3	200	-	77	230	-	92.1	-	-	0.27	-	-	0.01	0.01	-	-	-
2480-92 (MW-7)	4/17/2012	FGL	1390	-	7.97	-	-	57	11.9	230	13	84	230	310	22	0.03	-	0.2	-	0.123	0.197	0.0246	-	-	0.0469
2480-95 (MW-9)	11/17/2006	BSK	1100	710	8.2	320	-	33	6.5	230	4.6	87	110	390	<1	-	-	0.33	-	-	<0.05	0.28	-	-	-
2480-95 (MW-9)	11/29/2011	DL	1110	-	8.2	295	-	23	3.4	200	-	82	110	-	68.6	-	-	0.36	-	-	0.01	0.01	-	-	-
2480-95 (MW-9)	4/17/2012	FGL	1089	-	7.9	-	-	22	3.4	217	5.6	83	110	340	16	0.07	-	0.29	-	0.078	0.675	0.1108	-	-	0.0286
3730-74 (CC-1)	11/8/1994	JML	270	-	8.8	-	-	-	-	62	-	-	18	-	3.5	-	-	0.19	-	-	-	-	-	-	-
3730-74 (CC-1)	9/29/1997	JML	300	-	8.2	-	11.7	-	-	67	-	-	14	116	1.8	-	-	0.1	-	-	-	-	-	-	-
3730-74 (CC-1)	6/4/1999	JML	860	-	8.6	-	12.9	2	ND	73	-	27	16	-	6.2	-	-	0.07	-	-	-	-	-	-	-
3730-74 (CC-1)	5/4/2001	JML	270	173	8.6	-	3.4	17	2	54	-	27	14	-	ND	-	-	0.04	-	-	-	-	-	-	-
3730-74 (CC-1)	8/6/2002	JML	250	160	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3730-74 (CC-1)	8/25/2003	JML(1)	260	170	8.7	107	24	ND	ND	74	-	30	14	-	ND	-	-	0.05	-	-	-	-	-	-	-
3730-74 (CC-1)	8/4/2004	JML(1)	440	282	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3730-74 (CC-1)	7/22/2005	JML	300	-	8.51	-	9.1	3.2	1.3	76	-	34	16	-	0.9	-	-	0.09	-	-	-	-	-	-	-
3730-74 (CC-1)	7/18/2006	JML	350	224	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3730-74 (CC-1)	7/25/2007	JML	290	186	-	105	12.4	2.6	0.4	79	-	44	15	-	<0.4	-	-	0.07	-	-	-	-	-	-	-
3730-74 (CC-1)	7/2/2013	JML	640	-	7.79	-	-	9.8	3.3	139	-	55.2	77.3	228	1.3	-	-	0.16	-	-	-	-	-	-	-
3730-74 (CC-1)	6/19/2014	FGL	239.8	-	8.59	-	-	1.4	0.13	52	0.63	18	7.8	89	<0.4	0.14	-	ND	-	0.026	0.338	0.01	-	-	0.206
3730-75 (CC-2)	11/8/1994	JML	320	-	8.8	-	-	-	-	67	-	-	32	-	3.5	-	-	0.19	-	-	-	-	-	-	-
3730-75 (CC-2)	9/29/1997	JML	400	-	8.3	-	32.3	-	-	92	-	-	21	140	1.8	-	-	0.1	-	-	-	-	-	-	-
3730-75 (CC-2)	5/4/2001	JML	350	224	8.6	-	4.3	16	2	69	-	55	27	-	ND	-	-	0.06	-	-	-	-	-	-	-
3730-75 (CC-2)	5/14/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
3730-75 (CC-2)	8/6/2002	JML	330	211	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3730-75 (CC-2)	8/25/2003	JML(1)	330	210	8.7	127	61.9	ND	ND	101	-	80	30	-	ND	-	-	0.06	-	-	-	-	-	-	-
3730-75 (CC-2)	8/4/2004	JML(1)	570	365	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3730-75 (CC-2)	7/22/2005	JML	420	-	8.27	-	20	1.6	0.4	109	-	56	33	-	ND	-	-	0.09	-	-	-	-	-	-	-
3730-75 (CC-2)	7/18/2006	JML	480	307	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3730-75 (CC-2)	7/25/2007	JML	400	256	-	119	16.8	2.6	0.4	109	-	86	33	-	<0.4	-	-	0.09	-	-	-	-	-	-	-
3730-75 (CC-2)	6/17/2013	FGL	464	349	8.5	130	-	3	<1	101	<1	51	34	160	<0.2	<0.1	-	<0.1	-	-	<0.05	<0.01	-	-	<0.02
3730-75 (CC-2)	6/19/2014	FGL	435	-	8.43	-	-	2.8	0.35	93	1.2	45	31	133	<0.4	0.08	-	ND	-	0.01	0.736	0.032	-	-	0.009
3421-61 (Card-1)	3/18/1999	JML	490	-	8.2	-	40.5	1	ND	132	-	56	50	-	2.2	-	-	0.31	-	-	-	-	-	-	-
3421-61 (Card-1)	5/4/2001	JML	510	326	8.1	-	5.7	15.8	2.6	93.3	-	60	65	-	ND	-	-	0.3	-	-	-	-	-	-	-
3421-61 (Card-1)	5/14/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
3421-61 (Card-1)	8/1/2002	JML	890	570	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3421-61 (Card-1)	9/17/2003	JML(1)	710	450	8.2	170	13.1	9	3	177	-	76	94	-	0.1	-	-	0.1	-	-	-	-	-	-	-
3421-61 (Card-1)	8/4/2004	JML(1)	1160	742	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3421-61 (Card-1)	8/23/2005	JML	690	-	7.89	-	12.7	8.8	2.6	167	-	76	90	-	0.9	-	-	0.11	-	-	-	-	-	-	-
3421-61 (Card-1)	8/10/2006	JML	1010	646	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3421-61 (Card-1)	7/26/2007	JML	640	406	-	154	13.5	8.2	2.2	169	-	78	92	-	0.4	-	-	0.1	-	-	-	-	-	-	-
3421-61 (Card-1)	7/21/2010	JML	650	-	8.09	-	-	3.4	0.7	170.1	-	124.9	83.7	144	2	-	-	0.292	-	-	-	-	-	-	-
3421-61 (Card-1)	7/28/2011	FGL	696	473	7.9	-	11.5	9	2	146	2	65	78	170	0.7	<100	-	<0.1	-	<0.01	0.14	0.1	-	-	<0.02
3421-61 (Card-1)	6/17/2013	FGL	696	504	7.8	170	-	9	2	144	1	61	77	210	2.2	<0.1	-	<0.1	-	-	0.05	0.09	-	-	<0.02
3421-61 (Card-1)	6/17/2014	FGL	718	-	8.03	-	-	11	3.1	143	2	68	84	179	<0.4	0.04	-	0.123	-	0.033	1.497	0.151	-	-	0.062

Table E-2 (continued)
Summary of Groundwater Quality Laboratory Results (Deep Zone, Composite and Lower Aquifer)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
City of Mendota																									
No. 3	4/4/1996	NA	1900	1300	7.9	-	11.3	65	10	370	-	390	600	230	<2	<0.1	2	-	<0.1	<0.05	0.55	0.54	-	<50	<0.05
No. 3	7/3/1996	NA	2000	1200	7.8	-	-	60	9	-	-	300	360	240	<2	1.4	<2	-	<0.1	<0.05	0.49	0.48	-	<50	<0.05
No. 3	10/9/1996	NA	2400	1500	7.5	-	11.7	77	13	420	-	440	350	200	<2	<0.1	<2	-	<0.1	<0.05	0.61	0.56	-	<50	<0.05
No. 3	11/14/1996	NA	2000	1400	-	-	-	-	-	-	-	440	360	-	-	-	-	-	-	-	0.5	0.52	-	-	-
No. 3	3/6/1997	NA	1700	1200	-	-	-	-	-	-	-	300	340	-	-	-	-	-	-	-	0.29	0.39	-	-	-
No. 3	4/3/1997	NA	2300	1400	8.2	-	13.5	66	11	450	-	420	350	200	<2	<0.1	3	-	<0.1	<0.05	0.48	0.5	-	-	<0.05
No. 3	5/1/1997	NA	2300	1400	-	-	-	-	-	-	-	420	350	-	-	-	-	-	-	-	0.46	0.52	-	-	-
No. 3	6/5/1997	NA	2700	1700	-	-	-	-	-	-	-	550	390	-	-	-	-	-	-	-	0.69	0.86	-	-	-
No. 3	7/3/1997	NA	2400	1600	8.1	-	11.7	83	15	440	-	480	380	210	<2	<0.1	2	-	<0.1	<0.05	0.52	0.62	-	<50	<0.05
No. 3	10/2/1997	BSK	2100	1400	7.9	-	12	71	13	420	6	420	350	210	<2	0.3	<2	-	<0.1	-	0.42	0.54	-	-	-
No. 3	9/3/1998	NA	2400	1500	-	-	-	-	-	-	-	440	420	-	-	-	-	-	-	-	0.26	0.32	-	-	-
No. 3	10/1/1998	NA	2400	1500	8.1	-	12.3	80	16	460	-	440	390	210	<2	<0.1	<2	-	<0.1	<0.05	0.56	0.66	-	<50	<0.05
No. 3	12/3/1998	NA	2400	1500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.4	0.59	-	-	-
No. 3	1/7/1999	NA	2400	1500	8.0	-	12.3	81	15	460	-	490	410	200	15	<0.1	<2	-	<0.1	<0.05	0.55	0.61	-	<50	<0.05
No. 3	4/1/1999	NA	2200	1400	8.1	-	11.5	72	18	420	-	340	380	210	<2	<0.1	4	-	<0.1	<0.05	0.31	0.56	-	<50	<0.05
No. 3	7/1/1999	NA	2400	1600	7.9	-	12.3	81	15	460	-	410	390	210	9	<0.1	<2	-	<0.1	<0.05	0.53	0.63	-	-	<0.05
No. 3	8/6/1999	FGL	2490	1570	7.7	-	13	70	13	450	6	440	410	270	<0.4	-	<2	1	-	-	0.4	0.6	-	-	-
No. 3	9/29/1999	FGL	2500	1540	7.8	-	11.8	73	14	420	6	440	390	280	<0.4	-	<2	1.1	-	-	0.4	0.6	-	<2	-
No. 3	11/4/1999	NA	2500	1500	-	-	-	-	-	-	-	460	400	-	-	-	-	-	-	-	0.39	0.51	-	-	-
No. 3	1/6/2000	BSK	2300	1500	7.6	200	13.9	67	12	470	6	460	380	244	<1	<2	2	-	0.07	<0.05	0.4	0.5	-	-	<0.05
No. 3	2/3/2000	BSK	2400	1500	-	-	-	-	-	-	-	430	350	-	-	-	-	-	-	-	0.41	0.48	-	-	-
No. 3	3/2/2000	BSK	2500	1500	-	-	-	-	-	-	-	430	380	-	-	-	-	-	-	-	0.39	0.47	-	-	-
No. 3	4/6/2000	BSK	2300	1500	7.9	200	12.3	66	11	410	4	410	360	244	<1	<2.5	2	-	0.06	<0.05	0.37	0.48	-	-	<0.05
No. 3	5/4/2000	NA	2500	1700	-	-	-	-	-	-	-	500	390	-	-	-	-	-	-	-	0.14	0.49	-	-	-
No. 3	6/1/2000	BSK	2300	1500	-	-	-	-	-	-	-	390	360	-	-	-	-	-	-	-	0.35	0.46	-	-	-
No. 3	11/1/2000	BSK	2800	1700	-	-	-	-	-	-	-	530	430	-	-	-	-	-	-	-	0.43	0.53	-	-	-
No. 3	11/9/2000	BSK	2900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
No. 3	11/16/2000	BSK	2600	1700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
No. 3	11/21/2000	BSK	2700	1700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
No. 3	11/30/2000	BSK	2600	1700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
No. 3	12/7/2000	BSK	2900	1800	7.6	200	13.5	97	17	550	6	580	390	244	-	-	-	-	-	<0.05	0.5	0.67	-	-	<0.05
No. 3	12/15/2000	BSK	2600	1700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
No. 3	12/21/2000	BSK	2700	1600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
No. 3	2/1/2001	NA	2600	1600	-	-	-	-	-	-	-	-	-	-	<20	-	-	-	-	-	-	-	-	-	-
No. 3	5/4/2001	NA	2000	1200	7.9	-	-	83	18	340	-	380	240	230	-	<2	<2	-	<0.1	<0.05	0.78	0.65	-	<50	<0.05
No. 3	10/2/2001	FGL	2660	1680	7.9	210	13	71	15	463	6	561	399	250	<0.4	0.2	<2	1.36	-	<0.01	0.42	0.56	-	-	<0.02
No. 3	10/2/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.1	<0.4	-
No. 3	5/13/2002	NA	2200	1400	7.8	-	9.5	78	15	350	-	-	-	210	<30	-	-	-	-	<0.05	-	-	-	-	<0.05
No. 3	9/2/2002	NA	2560	1546	-	-	-	-	-	-	-	703	479	-	-	-	-	-	-	-	0.25	0.42	-	-	-
No. 3	1/7/2003	NA	2540	1578	-	-	-	-	-	-	-	517	275	-	-	-	-	-	-	-	<0.1	0.4	-	-	-
No. 3	5/11/2007	NA	-	-	-	-	-	-	-	-	-	-	-	-	<2	-	-	-	-	-	-	-	-	-	-
No. 4	9/27/1990	BCL	2020	1230	7.7	-	12.5	54	9.6	380	3.8	336	299	262	<0.4	0.27	<2	0.72	0.002	-	<0.005	<0.01	-	<2	-
No. 4	2/15/1991	NA	2300	1400	7.9	-	7.8	120	19	350	-	440	320	270	<1	0.1	<10	-	0.18	<0.05	0.68	0.96	-	<5	<0.05
No. 4	5/2/1991	NA	2300	1400	7.8	-	8.7	100	19	360	-	410	330	270	<1	0.2	<10	-	0.12	<0.05	0.64	0.87	-	<5	<0.05
No. 4	8/1/1991	NA	2300	1400	8.1	-	10.2	89	17	400	-	480	330	270	<1	0.2	-	-	-	-	0.77	0.69	-	-	-
No. 4	12/12/1991	NA	2300	1400	-	-	-	-	-	-	-	410	330	-	-	-	-	-	-	-	-	-	-	-	-
No. 4	7/2/1992	NA	2500	1600	-	-	-	-	-	-	-	480	330	-	-	-	-	-	-	-	-	-	-	-	-

Table E-2 (continued)
Summary of Groundwater Quality Laboratory Results (Deep Zone, Composite and Lower Aquifer)

Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Cations				Anions					Trace Elements								
								Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
City of Mendota																									
No. 5	1/7/2003	NA	2570	1596	-	-	-	-	-	-	-	280	611	-	-	-	-	-	-	-	<0.1	0.23	-	-	-
No. 5	4/18/2006	NA	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-
No. 6	1/23/1996	NA	630	350	7.4	-	2.2	39	17	66	-	63	83	160	<2	0.1	<2	-	0.21	<0.05	7.7	1.6	-	<5	0.055
No. 7	6/12/2001	NA	732	468	8.3	133	27.2	2.9	0.339	184	2	86	87.9	162	<0.2	0.71	5.8	0.61	0.01	0.01	0.28	0.03	-	<2	0.03
No. 7	2/11/2003	NA	380	380	-	-	-	-	-	-	-	78	94	-	-	-	-	-	-	-	0.403	ND	-	-	-
No. 7	3/4/2003	NA	664	410	-	-	-	-	-	-	-	68	58	-	-	-	-	-	-	-	0.211	0.29	-	-	-
No. 7	4/1/2003	NA	720	428	-	-	-	-	-	-	-	80	73	-	-	-	-	-	-	-	0.191	ND	-	-	-
No. 7	5/6/2003	NA	783	492	-	-	-	-	-	-	-	110	99	-	-	-	-	-	-	-	-	-	-	-	-
No. 7	6/3/2003	NA	799	468	-	-	-	-	-	-	-	103	91	-	-	-	-	-	-	-	0.167	0.26	-	-	-
No. 7	7/1/2003	NA	799	508	-	-	-	-	-	-	-	101	86	-	-	-	-	-	-	-	0.118	0.21	-	-	-
No. 7	8/5/2003	NA	800	530	-	-	-	-	-	-	-	112	96	-	-	-	-	-	-	-	0.164	0.23	-	-	-
No. 7	10/7/2003	NA	805	502	-	-	-	-	-	-	-	109	95	-	-	-	-	-	-	-	0.152	ND	-	-	-
No. 7	11/4/2003	NA	818	484	-	-	-	-	-	-	-	111	86	-	-	-	-	-	-	-	0.181	ND	-	-	-
No. 7	12/2/2003	NA	815	486	-	-	-	-	-	-	-	96	85	-	-	-	-	-	-	-	0.39	ND	-	-	-
No. 7	1/13/2004	NA	822	512	-	-	-	-	-	-	-	116	104	-	-	-	-	-	-	-	0.2	0.025	-	-	-
No. 7	3/2/2004	BSK	310	230	-	-	-	-	-	-	-	-	33	-	-	-	-	-	-	-	0.08	0.01	-	-	-
No. 7	4/7/2004	NA	820	510	-	-	-	-	-	-	-	-	96	-	-	-	-	-	-	-	<0.1	0.03	-	-	-
No. 7	6/9/2004	NA	810	510	-	-	-	-	-	-	-	-	94	-	-	-	-	-	-	-	<0.1	0.03	-	-	-
No. 7	9/7/2004	NA	780	500	-	-	-	-	-	-	-	-	92	-	-	-	-	-	-	-	<0.1	0.03	-	-	-
No. 7	10/20/2004	NA	810	520	8.3	-	-	4.5	0.6	160	-	100	94	180	<2	0.8	8	-	<0.1	<0.05	<0.1	0.03	-	ND	<0.05
No. 7	12/7/2004	NA	770	510	-	-	-	-	-	-	-	-	93	-	-	-	-	-	-	-	<0.05	0.03	-	-	-
No. 7	3/1/2005	NA	850	530	-	-	-	-	-	-	-	-	95	-	-	-	-	-	-	-	0.06	0.02	-	-	-
No. 7	8/2/2005	NA	590	430	-	-	-	-	-	-	-	-	77	-	-	-	-	-	-	-	0.05	0.2	-	-	-
No. 7	10/4/2005	NA	790	510	-	-	-	-	-	-	-	-	95	-	-	-	-	-	-	-	ND	0.03	-	-	-
No. 7	1/4/2006	NA	800	500	-	-	-	-	-	-	-	-	95	-	-	-	-	-	-	-	0.061	0.025	-	-	-
No. 7	4/4/2006	NA	450	310	-	-	-	-	-	-	-	-	54	-	-	-	-	-	-	-	0.12	<0.1	-	-	-
No. 7	7/6/2006	NA	810	510	-	-	-	-	-	-	-	-	92	-	-	-	-	-	-	-	<0.1	0.03	-	-	-
No. 7	7/10/2006	NA	800	1000	-	-	-	-	-	-	-	-	91	-	-	-	-	-	-	-	<0.1	0.03	-	-	-
No. 7	10/4/2006	NA	820	510	-	-	-	-	-	-	-	-	66	-	-	-	-	-	-	-	<0.1	0.02	-	-	-
No. 7	1/9/2007	NA	820	500	-	-	-	-	-	-	-	-	96	-	-	-	-	-	-	-	<0.1	0.027	-	-	-
No. 7	4/3/2007	NA	790	500	-	-	-	-	-	-	-	-	93	-	-	-	-	-	-	-	<0.1	0.027	-	-	-
No. 7	4/26/2007	NA	-	-	-	-	-	-	-	-	-	-	-	-	<2	-	-	-	-	-	-	-	-	-	-
No. 7	5/11/2007	NA	706	-	-	-	-	-	<2	160	-	106	-	-	<2	0.9	8.1	-	<0.1	<0.05	<0.1	0.022	-	<5	<0.05
No. 7	7/10/2007	NA	800	490	-	-	-	-	-	-	-	-	90	-	-	-	-	-	-	-	<0.1	-	-	-	-
No. 7	10/2/2007	NA	770	480	-	-	-	-	-	-	-	-	91	-	-	-	-	-	-	-	<0.1	-	-	-	-
No. 7	10/23/2007	NA	798	510	7.19	-	-	<2	<2	180	-	112	96	123	-	0.5	8.6	-	<0.1	<0.05	ND	0.03	-	<5	<0.05
No. 7	3/26/2008	NA	-	-	-	-	-	-	-	-	-	-	-	-	<8.9	-	-	-	-	-	-	-	-	-	-
No. 7	4/2/2008	NA	800	490	-	-	-	-	-	-	-	-	90	-	-	-	-	-	-	-	ND	0.057	-	-	-
No. 7	2/23/2009	NA	500	420	-	-	-	-	-	-	-	-	82	-	-	-	-	-	-	-	0.245	0.0384	-	-	-
No. 7	4/14/2009	NA	910	500	-	-	-	-	-	-	-	-	94.3	-	-	-	-	-	-	-	<0.1	0.0329	-	-	-
No. 7	11/3/2009	NA	719	490	-	-	-	-	-	-	-	-	98.8	-	-	-	-	-	-	-	<0.1	0.0343	-	-	-
No. 7	1/12/2010	NA	-	510	-	-	-	-	-	-	-	-	97	-	-	-	-	-	-	-	<0.1	0.0364	-	-	-
No. 7	7/14/2010	NA	-	480	-	-	-	-	-	-	-	-	90	-	-	-	-	-	-	-	<0.1	0.0387	-	-	-
No. 7	1/11/2011	NA	-	490	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	0.0523	-	-	-
No. 7	2/28/2011	NA	-	-	-	-	-	-	-	-	-	-	88.3	-	<2	-	-	-	-	-	-	-	-	-	-
No. 7	5/10/2011	NA	810	480	-	-	-	-	-	-	-	-	94	-	-	-	-	-	-	-	-	-	-	-	-
No. 7	7/12/2011	NA	750	490	-	-	-	-	-	-	-	-	85	-	-	-	-	-	-	-	-	-	-	-	-

Table E-2 (continued)
Summary of Groundwater Quality Laboratory Results (Deep Zone, Composite and Lower Aquifer)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab [1]	EC [2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity [3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3 [3] (mg/L)	NO_3 [3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
City of Mendota																									
No. 8	2/11/2003	NA	548	368	-	-	-	-	-	-	-	70	87	-	-	-	-	-	-	-	0.271	ND	-	-	-
No. 8	3/4/2003	NA	591	354	-	-	-	-	-	-	-	47	55	-	-	-	-	-	-	-	0.195	0.25	-	-	-
No. 8	5/6/2003	NA	289	232	-	-	-	-	-	-	-	15	29	-	-	-	-	-	-	-	0.758	ND	-	-	-
No. 8	6/24/2003	NA	291	266	-	-	-	-	-	-	-	13	26	-	-	-	-	-	-	-	0.708	ND	-	-	-
No. 8	7/1/2003	NA	292	186	-	-	-	-	-	-	-	13	24	-	-	-	-	-	-	-	0.635	ND	-	-	-
No. 8	8/5/2003	NA	292	220	-	-	-	-	-	-	-	14	27	-	-	-	-	-	-	-	0.682	0.2	-	-	-
No. 8	9/3/2003	NA	295	214	-	-	-	-	-	-	-	14	26	-	-	-	-	-	-	-	0.406	ND	-	-	-
No. 8	10/7/2003	NA	295	206	-	-	-	-	-	-	-	15	27	-	-	-	-	-	-	-	0.534	ND	-	-	-
No. 8	11/4/2003	NA	296	204	-	-	-	-	-	-	-	13	27	-	-	-	-	-	-	-	0.603	ND	-	-	-
No. 8	12/2/2003	NA	298	208	-	-	-	-	-	-	-	14	25	-	-	-	-	-	-	-	0.63	0.22	-	-	-
No. 8	1/13/2004	NA	302	210	-	-	-	-	-	-	-	16.6	31	-	-	-	-	-	-	-	0.24	<0.02	-	-	-
No. 8	3/2/2004	BSK	300	200	-	-	-	-	-	-	-	-	34	-	-	-	-	-	-	-	0.1	0.01	-	-	-
No. 8	4/7/2004	NA	300	220	-	-	-	-	-	-	-	-	33	-	-	-	-	-	-	-	0.11	<0.02	-	-	-
No. 8	6/9/2004	NA	340	240	-	-	-	-	-	-	-	-	37	-	-	-	-	-	-	-	0.17	0.02	-	-	-
No. 8	9/7/2004	NA	300	220	-	-	-	-	-	-	-	-	34	-	-	-	-	-	-	-	0.14	<0.02	-	-	-
No. 8	10/20/2004	NA	310	230	8.6	-	-	0.4	0.1	69	-	18	35	93	<2	0.4	<2	-	<0.1	<0.05	0.39	0.02	-	ND	<0.05
No. 8	12/7/2004	NA	300	230	-	-	-	-	-	-	-	-	35	-	-	-	-	-	-	-	0.1	0.01	-	-	-
No. 8	3/1/2005	NA	330	530	-	-	-	-	-	-	-	-	35	-	-	-	-	-	-	-	0.2	0.01	-	-	-
No. 8	8/2/2005	NA	540	380	-	-	-	-	-	-	-	-	70	-	-	-	-	-	-	-	0.07	0.03	-	-	-
No. 8	10/4/2005	NA	560	230	-	-	-	-	-	-	-	-	71	-	-	-	-	-	-	-	0.12	0.04	-	-	-
No. 8	12/7/2005	NA	300	230	-	-	-	-	-	-	-	-	35	-	-	-	-	-	-	-	0.1	0.01	-	-	-
No. 8	1/4/2006	NA	320	220	-	-	-	-	-	-	-	-	37	-	-	-	-	-	-	-	0.12	0.01	-	-	-
No. 8	4/4/2006	NA	310	230	-	-	-	-	-	-	-	-	37	-	-	-	-	-	-	-	0.12	<0.02	-	-	-
No. 8	7/6/2006	NA	330	230	-	-	-	-	-	-	-	-	38	-	-	-	-	-	-	-	0.14	<0.02	-	-	-
No. 8	7/10/2006	NA	320	110	-	-	-	-	-	-	-	-	36	-	-	-	-	-	-	-	0.22	<0.02	-	-	-
No. 8	10/4/2006	NA	320	220	-	-	-	-	-	-	-	-	39	-	-	-	-	-	-	-	0.11	<0.02	-	-	-
No. 8	1/9/2007	NA	330	220	-	-	-	-	-	-	-	-	38	-	-	-	-	-	-	-	<0.1	<0.02	-	-	-
No. 8	4/3/2007	NA	320	220	-	-	-	-	-	-	-	-	38	-	-	-	-	-	-	-	0.12	<0.02	-	-	-
No. 8	4/26/2007	NA	-	-	-	-	-	-	-	-	-	-	-	-	<2	-	-	-	-	-	-	-	-	-	-
No. 8	5/11/2007	NA	302	-	-	-	-	-	<2	74	-	22.3	-	-	<2	0.5	<2	-	<0.1	<0.05	<0.1	<0.02	-	<5	<0.05
No. 8	7/10/2007	NA	330	220	-	-	-	-	-	-	-	-	37	-	-	-	-	-	-	-	0.12	-	-	-	-
No. 8	10/2/2007	NA	330	220	-	-	-	-	-	-	-	-	39	-	-	-	-	-	-	-	0.12	-	-	-	-
No. 8	10/23/2007	NA	334	240	7.47	-	-	<2	<2	66	-	20.6	38	80	-	0.4	<2	-	<0.1	<0.05	0.52	ND	-	<5	<0.05
No. 8	3/26/2008	NA	-	-	-	-	-	-	-	-	-	-	-	-	<8.9	-	-	-	-	-	-	-	-	-	-
No. 8	4/2/2008	NA	330	220	-	-	-	-	-	-	-	22	38	-	-	-	-	-	-	-	0.3	1.2	-	-	-
No. 8	2/23/2009	NA	500	430	-	-	-	-	-	-	-	-	81.9	-	-	-	-	-	-	-	0.3	0.0366	-	-	-
No. 8	4/14/2009	NA	830	-	-	-	-	-	-	-	-	-	90.2	-	-	-	-	-	-	-	<0.1	0.0255	-	-	-
No. 8	11/3/2009	NA	337	250	-	-	-	-	-	-	-	-	46	-	-	-	-	-	-	-	0.16	0.0212	-	-	-
No. 8	1/12/2010	NA	-	470	-	-	-	-	-	-	-	-	92	-	-	-	-	-	-	-	<0.1	0.0304	-	-	-
No. 8	7/14/2010	NA	-	270	-	-	-	-	-	-	-	-	46.7	-	-	-	-	-	-	-	0.15	0.0257	-	-	-
No. 8	1/11/2011	NA	-	460	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	0.0415	-	-	-
No. 8	2/28/2011	NA	-	-	-	-	-	-	-	-	-	-	87.9	-	<2	-	-	-	-	-	-	-	-	-	-
No. 8	5/10/2011	NA	360	240	-	-	-	-	-	-	-	-	43	-	-	-	-	-	-	-	-	-	-	-	-
No. 8	7/12/2011	NA	770	500	-	-	-	-	-	-	-	-	85	-	-	-	-	-	-	-	-	-	-	-	-
No. 8	8/2/2011	NA	790	480	-	-	-	-	-	-	-	-	85	-	-	-	-	-	-	-	-	-	-	-	-
No. 8	9/27/2011	NA	800	500	-	-	-	-	-	-	-	-	93	-	-	-	-	-	-	-	-	-	-	-	-
No. 8	10/18/2011	NA	340	250	-	-	-	-	-	-	-	-	40	-	-	-	-	-	-	-	-	-	-	-	-

Table E-2 (continued)
Summary of Groundwater Quality Laboratory Results (Deep Zone, Composite and Lower Aquifer)

								Cations				Anions					Trace Elements									
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
City of Mendota																										
No. 9	6/3/2003	NA	724	416	-	-	-	-	-	-	-	80	84	-	-	-	-	-	-	-	0.156	0.21	-	-	-
No. 9	7/1/2003	NA	732	402	-	-	-	-	-	-	-	77	80	-	-	-	-	-	-	-	0.149	ND	-	-	-
No. 9	8/5/2003	NA	728	468	-	-	-	-	-	-	-	82	88	-	-	-	-	-	-	-	0.134	ND	-	-	-
No. 9	10/7/2003	NA	720	450	-	-	-	-	-	-	-	80	85	-	-	-	-	-	-	-	0.152	ND	-	-	-
No. 9	11/14/2003	NA	734	454	-	-	-	-	-	-	-	82	87	-	-	-	-	-	-	-	0.2	ND	-	-	-
No. 9	12/2/2003	NA	734	448	-	-	-	-	-	-	-	76	80	-	-	-	-	-	-	-	0.16	0.22	-	-	-
No. 9	1/13/2004	NA	746	460	-	-	-	-	-	-	-	91	96	-	-	-	-	-	-	-	0.16	<0.02	-	-	-
No. 9	3/2/2004	BSK	350	260	-	-	-	-	-	-	-	-	41	-	-	-	-	-	-	-	0.07	0.01	-	-	-
No. 9	4/7/2004	NA	750	480	-	-	-	-	-	-	-	-	90	-	-	-	-	-	-	-	<0.1	0.02	-	-	-
No. 9	4/27/2004	NA	810	500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	ND	ND	-	-	-
No. 9	6/9/2004	NA	360	240	-	-	-	-	-	-	-	-	41	-	-	-	-	-	-	-	<0.1	0.02	-	-	-
No. 9	9/7/2004	NA	720	460	-	-	-	-	-	-	-	-	90	-	-	-	-	-	-	-	<0.1	0.02	-	-	-
No. 9	10/20/2004	NA	740	470	8.4	-	-	3	0.3	150	-	85	89	170	<2	0.6	2	-	<0.1	<0.05	<0.1	0.02	-	ND	<0.05
No. 9	12/7/2004	NA	710	480	-	-	-	-	-	-	-	-	90	-	-	-	-	-	-	-	<0.05	0.02	-	-	-
No. 9	3/1/2005	NA	780	480	-	-	-	-	-	-	-	-	91	-	-	-	-	-	-	-	ND	0.02	-	-	-
No. 9	8/2/2005	NA	670	450	-	-	-	-	-	-	-	-	89	-	-	-	-	-	-	-	ND	0.02	-	-	-
No. 9	10/4/2005	NA	560	370	-	-	-	-	-	-	-	-	71	-	-	-	-	-	-	-	ND	0.01	-	-	-
No. 9	1/4/2006	NA	740	460	-	-	-	-	-	-	-	-	92	-	-	-	-	-	-	-	ND	0.019	-	-	-
No. 9	4/4/2006	NA	480	320	-	-	-	-	-	-	-	-	60	-	-	-	-	-	-	-	<0.1	<0.1	-	-	-
No. 9	7/6/2006	NA	740	490	-	-	-	-	-	-	-	-	87	-	-	-	-	-	-	-	<0.1	0.02	-	-	-
No. 9	10/4/2006	NA	750	460	-	-	-	-	-	-	-	-	92	-	-	-	-	-	-	-	<0.1	<0.02	-	-	-
No. 9	1/9/2007	NA	760	450	-	-	-	-	-	-	-	-	92	-	-	-	-	-	-	-	<0.1	0.02	-	-	-
No. 9	4/3/2007	NA	740	450	-	-	-	-	-	-	-	-	88	-	-	-	-	-	-	-	<0.1	0.02	-	-	-
No. 9	4/26/2007	NA	-	-	-	-	-	-	-	-	-	-	-	-	<2	-	-	-	-	-	-	-	-	-	-
No. 9	5/11/2007	NA	675	-	-	-	-	-	<2	150	-	90	-	-	<2	0.8	2.8	-	<0.1	<0.05	<0.1	<0.02	-	<5	<0.05
No. 9	7/10/2007	NA	730	420	-	-	-	-	-	-	-	-	84	-	-	-	-	-	-	-	<0.1	-	-	-	-
No. 9	10/2/2007	NA	710	440	-	-	-	-	-	-	-	-	87	-	-	-	-	-	-	-	<0.1	-	-	-	-
No. 9	10/23/2007	NA	716	470	7.56	-	-	<2	<2	167	-	86.6	91	133	-	0.47	3.3	-	<0.1	<0.05	ND	0.021	-	<5	<0.05
No. 9	3/26/2008	NA	-	-	-	-	-	-	-	-	-	-	-	-	<8.9	-	-	-	-	-	-	-	-	-	-
No. 9	4/2/2008	NA	750	460	-	-	-	-	-	-	-	76	88	-	-	-	-	-	-	-	0.168	0.056	-	-	-
No. 9	2/23/2009	NA	500	420	-	-	-	-	-	-	-	-	80.2	-	-	-	-	-	-	-	0.246	0.0363	-	-	-
No. 9	4/14/2009	NA	820	460	-	-	-	-	-	-	-	-	89.3	-	-	-	-	-	-	-	<0.1	0.0258	-	-	-
No. 9	11/3/2009	NA	676	460	-	-	-	-	-	-	-	-	92.4	-	-	-	-	-	-	-	<0.1	0.0336	-	-	-
No. 9	1/12/2010	NA	-	450	-	-	-	-	-	-	-	-	91	-	-	-	-	-	-	-	<0.1	0.0302	-	-	-
No. 9	7/14/2010	NA	-	340	-	-	-	-	-	-	-	-	64.6	-	-	-	-	-	-	-	0.13	0.0259	-	-	-
No. 9	1/11/2011	NA	-	460	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	0.0413	-	-	-
No. 9	2/28/2011	NA	-	-	-	-	-	-	-	-	-	-	88.1	-	<2	-	-	-	-	-	-	-	-	-	-
No. 9	5/10/2011	NA	760	430	-	-	-	-	-	-	-	-	90	-	-	-	-	-	-	-	-	-	-	-	-
No. 9	7/12/2011	NA	690	400	-	-	-	-	-	-	-	-	81	-	-	-	-	-	-	-	-	-	-	-	-
No. 9	8/2/2011	NA	720	410	-	-	-	-	-	-	-	-	71	-	-	-	-	-	-	-	-	-	-	-	-
No. 9	9/27/2011	NA	730	450	-	-	-	-	-	-	-	-	88	-	-	-	-	-	-	-	-	-	-	-	-
No. 9	10/18/2011	NA	740	480	-	-	-	-	-	-	-	-	89	-	-	-	-	-	-	-	-	-	-	-	-
No. 9	11/1/2011	NA	750	470	-	-	-	-	-	-	-	-	94	-	-	-	-	-	-	-	-	-	-	-	-
No. 9	12/6/2011	NA	710	490	-	-	-	-	-	-	-	-	93	-	-	-	-	-	-	-	-	-	-	-	-
No. 9	12/13/2011	NA	-	-	-	-	-	-	-	-	-	-	-	-	<2	-	-	-	-	-	-	-	-	-	-
No. 9	1/10/2012	NA	730	430	-	-	-	-	-	-	-	-	96	-	-	-	-	-	-	-	-	-	-	-	-
No. 9	2/7/2012	NA	730	450	-	-	-	-	-	-	-	-	82	-	-	-	-	-	-	-	-	-	-	-	-

Table E-2 (continued)
Summary of Groundwater Quality Laboratory Results (Deep Zone, Composite and Lower Aquifer)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
U.S. Geological Survey																									
31J5	7/8/2003	FGL	9900	6900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31J5	6/18/2004	FGL	10300	7200	7.3	250	-	416	228	1860	15	1740	2530	310	<0.4	1	<2	3.5	-	<0.01	2.2	3.57	-	-	<0.02
31J5	6/18/2004	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13.1	<0.4	-
31J5	8/7/2006	FGL	10000	6700	7.8	220	-	360	194	2000	20	1650	2470	270	<0.4	<0.1	4	3.7	-	<0.01	2.33	3.1	-	-	<0.02
31J5	8/7/2006	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21.3	<0.4	-
31J5	9/19/2007	FGL	10200	6870	7.7	230	20.5	392	199	2000	18	1500	1160	280	<0.4	<0.1	7	4.02	-	<0.01	1.98	3	-	-	<0.02
31J5	9/19/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18.3	<0.4	-
31J5	9/17/2008	FGL	10300	6920	8.1	100	16.1	394	198	1570	20	1800	2480	200	<0.4	<0.5	5	3.8	-	<0.01	2.22	2.99	-	-	<0.02
31J5	9/17/2008	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24.5	<0.4	-
31J5	5/12/2010	FGL	10000	6780	7.3	220	16.8	389	199	1630	14	1800	2550	260	<0.8	0.3	<2	3.8	-	<0.01	2	2.92	22	-	<0.02
31J5	5/12/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
31J5	5/9/2012	FGL	7500	4950	7.8	190	-	281	138	1280	16	1300	1820	230	<1.8	0.3	9	3.1	0.367	<0.01	0.84	1.88	21	-	<0.02
31J5	5/9/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	-
31J5	5/7/2013	FGL	9830	6950	7.4	220	-	358	182	1990	17	1500	2300	270	0.5	<0.2	8	4.4	-	<0.01	1.96	2.56	23	32	<0.02
31J5	5/20/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
31J5	5/20/2014	FGL	8640	5920	7.62	200	-	288	150	1510	16	1480	2230	240	<0.4	<0.1	6	3.5	0.265	<0.01	1.82	2.12	21	-	<0.02
10A4	9/28/1999	FGL	2820	2370	7.5	130	2.5	221	167	200	3	1370	129	160	5.5	-	2	2.1	-	-	<0.25	0.16	-	-	-
Covanta Mendota																									
Well 6A	5/17/1991	BCL	990	625	8.6	180	-	-	-	209	1	83	133	-	-	0.12	-	0.2	-	-	0.058	0.068	-	-	-
Well 6A	8/12/1994	BD	1050	-	8.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Well 6A	9/19/1996	BD	1200	-	8.4	225	-	-	-	258	-	119	172	-	-	-	-	-	-	<0.05	<0.05	-	-	-	<0.05
Well 6A	9/9/1999	BD	1290	-	8.5	236	-	-	-	269	-	127	173	-	-	-	-	-	-	<0.05	0.35	-	-	-	-
Well 6A	5/11/2000	BD	1340	-	8.4	223	-	-	-	272	-	144	208	-	-	-	-	-	-	<0.05	0.1	-	-	-	-
Well 6A	11/2/2000	BD	1290	-	8.4	233	-	-	-	276	-	128	199	-	-	-	-	-	-	<0.05	0.17	-	-	-	-
Well 6A	8/23/2001	BD	1330	-	8.3	241	-	-	-	287	-	143	196	-	-	-	-	-	-	<0.05	0.09	-	-	-	-
Well 6A	4/18/2002	BD	1460	-	8.4	242	-	-	-	296	-	144	218	-	-	-	-	-	-	<0.05	0.06	-	-	-	<0.01
Well 6A	6/13/2002	BD	1430	-	8.4	237	-	-	-	307	-	160	216	-	-	-	-	-	-	<0.05	0.21	-	-	-	-
Well 6A	3/11/2004	BD	2100	-	7.9	211	-	-	-	414	-	196	430	-	-	-	-	-	-	<0.05	0.39	-	-	-	-
Well 6A	6/1/2005	BD	1430	-	-	237	-	-	-	-	-	-	202	-	-	-	-	-	-	-	-	-	-	-	-
Well 6A	7/1/2005	BD	1350	-	-	231	-	-	-	-	-	-	196	-	-	-	-	-	-	-	-	-	-	-	-
Well 6A	8/1/2005	BD	1400	-	-	229	-	-	-	-	-	-	207	-	-	-	-	-	-	-	-	-	-	-	-
Well 6A	10/1/2005	BD	1850	-	-	226	-	-	-	-	-	-	315	-	-	-	-	-	-	-	-	-	-	-	-
Well 6A	12/1/2005	BD	2230	-	-	172	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Well 6A	2/1/2006	BD	2220	-	-	214	-	-	-	-	-	-	506	-	-	-	-	-	-	-	-	-	-	-	-
Well 6A	5/1/2006	BD	1800	-	-	218	-	-	-	-	-	-	322	-	-	-	-	-	-	-	-	-	-	-	-
Well 6A	6/1/2008	NA	2046	-	-	221	-	-	-	-	-	-	355	-	-	-	-	-	-	-	-	-	-	-	-
Well 6A	11/1/2008	NA	2585	-	-	212	-	-	-	-	-	-	519	-	-	-	-	-	-	-	-	-	-	-	-
Well 6A	4/1/2009	NA	2417	-	-	211	-	-	-	-	-	-	446	-	-	-	-	-	-	-	-	-	-	-	-
Well 6A	6/1/2009	NA	2019	-	-	223	-	-	-	-	-	-	378	-	-	-	-	-	-	-	-	-	-	-	-
Well 6A	2/8/2010	NA	3109	-	-	198	-	-	-	-	-	-	700	-	-	-	-	-	-	-	-	-	-	-	-
Well 6A	1/12/2011	NA	2834	-	-	214	-	-	-	-	-	-	590	-	-	-	-	-	-	-	-	-	-	-	-
Well 6A	10/13/2011	NA	3135	-	-	206	-	-	-	-	-	-	662	-	-	-	-	-	-	-	-	-	-	-	-
Well 6A	1/7/2013	NA	2879	-	8.24	206	-	-	-	548	5.3	351	567	-	<1	-	-	-	-	<0.05	0.07	-	-	-	<0.05
Hansen Farms																									
7C1	8/3/1999	FGL	8860	5700	7.8	-	18.2	216	140	1400	8	1020	2380	320	7	-	10	3.9	-	-	0.32	0.28	-	-	-

Table E-2 (continued)
Summary of Groundwater Quality Laboratory Results (Deep Zone, Composite and Lower Aquifer)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Terra Linda Farms																									
TLF-6d	5/11/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
TLF-6d	8/15/2011	FGL	1540	910	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-6d	5/8/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.2	-
TLF-6d	5/8/2012	FGL	2110	1200	8.3	160	-	18	2	439	5	209	490	190	<1.8	0.2	<2	0.6	-	<0.01	<0.05	0.05	6	-	<0.02
TLF-6d	5/8/2013	FGL	2040	1190	7.8	170	-	20	2	437	5	198	440	210	<0.4	0.4	<2	0.6	-	<0.01	<0.05	0.06	6	5.47	<0.02
TLF-6d	5/21/2014	CAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	-
TLF-6d	5/21/2014	FGL	2210	1310	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-6d	5/21/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
TLF-12d	8/25/1999	FGL	651	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-12d	9/22/1999	FGL	664	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-12d	7/13/2000	FGL	675	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-12d	10/1/2001	FGL	733	450	8.4	140	15.6	5	<1	146	2	65	104	170	<0.4	0.5	<2	0.35	-	<0.01	0.12	0.05	-	-	<0.02
TLF-12d	10/1/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.5	<0.4	-
TLF-12d	5/8/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
TLF-12d	5/8/2012	FGL	1740	1060	8.4	160	-	17	2	333	5	330	259	200	3.5	0.4	<2	0.6	-	0.52	0.92	0.17	10	-	0.9
TLF-14d	8/25/1999	FGL	971	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-14d	9/22/1999	FGL	1035	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-14d	7/13/2000	FGL	1060	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-14d	6/26/2001	FGL	1070	650	8.4	160	24.4	5	<1	228	3	113	162	200	<0.4	0.6	<2	0.51	-	<0.01	<0.05	0.02	8	-	<0.02
TLF-14d	6/26/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
TLF-14d	9/12/2001	FGL	1190	730	8.5	170	24.7	6	<1	248	3	140	183	210	<0.4	0.7	<2	0.56	-	<0.01	<0.05	0.02	-	-	<0.02
TLF-14d	9/12/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.7	<0.4	-
TLF-14d	10/2/2001	FGL	1110	690	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-14d	10/2/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
TLF-14d	6/25/2002	FGL	1250	780	8.3	170	24.4	6	<1	245	3	134	196	210	<0.4	0.3	<2	0.5	-	<0.01	<0.05	0.03	-	-	<0.02
TLF-14d	6/25/2002	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.7	<0.4	-
TLF-14d	5/21/2007	CLS	1400	840	7.89	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-14d	9/18/2007	FGL	1560	970	8.2	180	26.5	11	1	342	3	172	278	210	0.8	0.4	<2	0.5	-	<0.01	<0.05	0.04	-	-	<0.02
TLF-14d	9/18/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.4	<0.4	-
TLF-14d	9/16/2008	FGL	1650	950	8.0	170	22.9	12	1	307	4	173	280	210	<0.4	0.4	<2	0.6	-	<0.01	0.05	0.05	-	-	<0.02
TLF-14d	9/16/2008	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.25	<0.4	-
TLF-14d	5/26/2009	FGL	1680	1000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-14d	5/12/2010	FGL	1790	1030	8.0	170	21.4	15	2	332	4	207	329	210	<0.4	0.4	<2	0.6	-	<0.01	0.07	0.06	7	-	<0.02
TLF-14d	5/12/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
TLF-18d	7/13/2000	FGL	1440	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-18d	9/19/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.8	<0.4	-
TLF-18d	9/19/2007	FGL	1230	770	8.5	210	25.8	8	<1	265	2	129	185	250	<0.4	0.2	<2	0.3	-	<0.01	<0.05	0.04	-	-	<0.02
TLF-18d	9/16/2008	FGL	1340	780	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-18d	8/15/2011	FGL	829	500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TLF-18d	5/8/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
TLF-18d	5/8/2012	FGL	1410	850	8.3	190	-	11	1	305	3	178	229	230	<1.8	0.1	<2	0.4	-	<0.01	<0.05	0.06	3	-	<0.02
TL-1	7/13/2000	FGL	877	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TL-1	6/25/2002	FGL	1450	880	8.1	210	19.4	14	1	278	3	157	220	260	<0.4	0.2	<2	0.4	-	<0.01	<0.05	0.08	-	-	<0.02
TL-1	6/25/2002	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.5	<0.4	-
TL-6	9/22/1999	FGL	4040	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table E-2 (continued)
Summary of Groundwater Quality Laboratory Results (Deep Zone, Composite and Lower Aquifer)

								Cations					Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Meyers Farming																										
MS-5	3/23/1999	TL	-	1700	-	-	-	-	-	-	-	-	600	-	-	-	-	0.82	-	-	-	-	-	<2	-
MS-5	8/5/1999	FGL	2940	1710	8.3	-	24	26	12	590	3	220	570	390	<0.4	-	<2	0.8	-	-	<0.05	0.09	-	-	-
MS-5	8/25/1999	FGL	2970	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS-5	9/22/1999	FGL	2820	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS-5	9/27/1999	FGL	3060	1750	5.2	-	23.8	27	11	580	3	250	620	410	<0.4	-	<2	0.9	-	-	<0.05	0.1	-	<2	-
MS-5	7/13/2000	FGL	2970	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS-5	8/24/2000	FGL	2890	1670	8.0	340	20.5	28	16	548	2	300	450	390	<0.4	0.2	-	0.8	-	0.02	0.08	0.12	-	<10	0.16
MS-5	6/26/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
MS-5	6/26/2001	FGL	3030	1790	8.1	310	23.7	28	13	604	3	333	549	380	<0.4	0.4	<2	0.87	-	<0.01	0.07	0.11	22	-	<0.02
MS-5	9/10/2001	TL	3000	1800	-	-	-	-	-	-	-	-	-	-	-	-	-	0.83	-	-	-	-	18	-	-
MS-5	10/3/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
MS-5	10/3/2001	FGL	3130	1820	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS-5	6/27/2002	FGL	3110	1860	8.4	290	22	32	14	592	3	320	670	360	<0.4	0.3	<2	0.8	-	<0.01	0.06	0.12	-	-	<0.02
MS-5	6/27/2002	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16.6	<0.4	-
MS-5	8/20/2002	CLS	3200	1800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS-5	8/20/2002	FGL	3190	1890	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS-5	8/20/2002	TL	3200	1900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MS-5	7/9/2003	FGL	3190	1830	8.2	280	-	34	15	667	3	350	710	340	<0.4	0.4	<2	0.89	-	<0.01	0.07	0.13	-	-	<0.02
MS-5	7/9/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16.8	<0.4	-
Meyers Farm Water Bank																										
DW-1	12/21/2007	BCL	2400	1400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DW-1	4/17/2008	BCL	2000	1100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DW-1	4/21/2008	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.46	<0.4	-
DW-1	4/21/2008	BCL	-	-	-	-	-	-	-	-	-	-	-	280	-	-	-	-	-	-	-	-	-	-	-
DW-1	10/4/2008	BCL	1970	1100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DW-1	7/22/2009	BCL	2940	1800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.079	-	-	-	-	-	-
Farmers Water District																										
R-1	6/25/2001	FGL	430	270	8.8	110	12.5	2	<1	87	<1	45	34	130	<0.1	0.1	<2	0.09	-	<0.01	0.11	<0.01	5	-	<0.02
R-1	6/25/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
R-1	10/2/2001	FGL	444	290	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R-1	10/2/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
R-1	8/20/2002	CLS	430	270	-	110	11.9	2	<1	87	<1	47	35	122	-	-	-	-	-	-	-	-	-	-	-
R-1	8/20/2002	FGL	436	290	8.8	110	13.7	2	<1	95	<1	42	35	140	<0.4	<0.1	-	0.1	-	<0.01	0.08	<0.01	-	-	<0.02
R-1	8/20/2002	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.8	<0.4	-
R-1	8/20/2002	TL	440	260	-	-	15.9	2	0.3	95	1	46	35	130	-	-	-	-	-	-	-	-	-	-	-
R-1	7/9/2003	FGL	465	320	8.8	120	-	2	<1	111	<1	50	41	140	<0.4	0.3	<2	0.1	-	<0.01	<0.05	<0.01	-	-	<0.02
R-1	7/9/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.4	<0.4	-
R-1	6/17/2004	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	<0.4	-
R-1	6/17/2004	FGL	441	300	8.8	120	-	3	ND	99	ND	54	28	130	<0.4	0.1	<2	<0.1	-	<0.01	0.09	0.02	-	-	<0.02
R-1	10/26/2005	FGL	461	330	8.7	130	-	2	<1	93	<1	50	27	160	<0.4	<0.1	<2	<0.1	-	<0.01	0.57	0.01	-	-	<0.02
R-1	10/26/2005	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.5	<0.4	-
R-1	8/8/2006	FGL	476	310	9.1	130	-	2	<1	100	<1	55	29	120	<0.4	<0.1	<2	<0.1	0.0112	<0.01	0.86	0.03	-	-	<0.02
R-1	8/8/2006	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	<0.4	-
R-1	5/16/2007	CLS	450	300	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R-1	5/27/2009	FGL	571	350	8.7	140	21	3	<1	132	<1	65	43	170	<0.4	<0.1	<2	<0.1	-	<0.01	<0.05	0.01	4	-	<0.02
R-1	5/27/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-

Table E-2 (continued)
Summary of Groundwater Quality Laboratory Results (Deep Zone, Composite and Lower Aquifer)

Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Cations				Anions					Trace Elements								
								Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Farmers Water District																									
R-3	5/8/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
R-3	5/7/2013	FGL	982	620	8.1	240	-	20	3	208	2	111	81	300	1	<0.1	<2	<0.1	-	<0.01	0.08	0.09	1	1	<0.02
R-3	5/20/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
R-3	5/20/2014	FGL	999	630	7.93	240	-	20	3	191	2	121	92	300	<0.4	<0.1	<2	0.1	0.0374	<0.01	0.1	0.09	1	-	<0.02
R-4	10/1/2001	FGL	252	180	9.2	90	9.3	1	<1	55	<1	15	13	100	<0.4	0.2	3	0.08	-	<0.01	0.14	<0.01	-	-	<0.02
R-4	10/1/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.1	<0.4	-
R-4	6/17/2002	TL	240	150	8.7	84	13.7	1	0.1	56	<1	23	8.7	100	<2	-	-	<0.05	<0.01	<0.05	0.48	<0.03	-	-	<0.05
R-4	5/16/2007	CLS	500	320	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R-4	9/20/2007	FGL	281	180	8.9	90	<0.1	<1	<1	63	<1	19	19	90	<0.4	0.3	3	<0.05	-	<0.01	0.11	<0.01	-	-	<0.02
R-4	9/20/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.2	<0.4	-
R-4	9/18/2008	FGL	341	210	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R-4	5/27/2009	FGL	305	220	8.9	90	<0.1	<1	<1	68	<1	19	24	100	<0.4	0.3	4	0.1	-	<0.01	0.06	<0.01	4	-	<0.02
R-4	5/27/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
R-4	5/17/2010	FGL	617	360	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R-4	5/9/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
R-4	5/9/2012	FGL	621	370	8.7	120	-	3	<1	138	2	40	84	140	<1.8	0.4	3	0.3	0.0134	<0.01	0.07	0.01	10	-	<0.02
R-4	5/7/2013	FGL	659	420	8.6	120	-	4	<1	147	2	43	97	150	<0.4	0.4	3	0.3	-	<0.01	0.08	0.01	9	2.23	<0.02
R-4	5/21/2014	CAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	-
R-4	5/21/2014	FGL	608	370	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R-4	5/21/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
R-6	10/1/2001	FGL	558	350	8.7	110	10.1	7	<1	108	1	58	67	140	<0.4	0.2	<2	0.16	-	<0.01	0.06	0.03	-	-	<0.02
R-6	10/1/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.1	<0.4	-
R-6	6/17/2002	TL	480	290	8.2	100	6.3	14	1.4	93	2	47	51	130	<2	-	-	0.1	0.011	<0.05	0.88	0.086	-	-	<0.05
R-6	5/16/2007	CLS	470	280	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R-6	9/18/2007	FGL	510	310	8.7	110	10.1	8	<1	104	<1	55	64	130	<0.4	0.1	<2	<0.1	-	<0.01	<0.05	0.03	-	-	<0.02
R-6	9/18/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.3	<0.4	-
R-6	5/27/2009	FGL	498	300	8.4	100	8.9	10	<1	102	1	50	54	130	<0.4	0.1	<2	0.1	-	0.02	0.14	0.04	4	-	<0.02
R-6	5/27/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
R-6	5/9/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
R-6	5/9/2012	FGL	503	310	8.6	100	-	9	<1	100	1	55	61	120	<1.8	<0.1	11	0.1	-	<0.01	<0.05	0.03	30	-	<0.02
R-7	10/1/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.8	<0.4	-
R-7	10/1/2001	FGL	476	300	8.7	110	7.4	9	<1	88	1	58	43	130	<0.4	<0.1	<2	<0.05	-	<0.01	<0.05	0.02	-	-	<0.02
R-7	6/17/2002	TL	470	280	8.4	100	9	8	0.5	98	2	55	42	130	<2	-	-	0.1	<0.01	<0.05	<0.1	<0.03	-	-	<0.05
R-7	5/16/2007	CLS	460	280	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R-7	9/20/2007	FGL	459	300	8.3	110	10.1	7	<1	97	<1	60	42	130	<0.4	0.2	<2	<0.05	-	<0.01	<0.05	0.01	-	-	<0.02
R-7	9/20/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.1	<0.4	-
R-7	9/18/2008	FGL	466	280	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R-7	5/27/2009	FGL	452	270	8.6	100	10.9	6	<1	97	1	52	38	120	<0.4	0.1	<2	0.1	-	<0.01	<0.05	0.01	3	-	<0.02
R-7	5/27/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
R-7	5/17/2010	FGL	445	290	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R-7	5/9/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
R-7	5/9/2012	FGL	419	260	8.7	90	-	7	<1	84	1	46	38	110	<1.8	0.1	<2	0.1	0.0054	<0.01	<0.05	0.01	4	-	<0.02
R-7	5/7/2013	FGL	423	290	8.5	90	-	6	<1	88	1	45	36	110	<0.4	<0.1	<2	0.1	-	<0.01	<0.05	0.01	5	<1	<0.02
R-8	10/2/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.4	<0.4	-
R-8	10/2/2001	FGL	587	340	8.9	130	15.5	3	<1	121	1	59	66	160	<0.4	0.3	<2	0.22	-	<0.01	0.12	<0.01	-	-	<0.02
R-8	8/20/2002	FGL	616	420	8.7	140	18.3	2	<1	127	1	55	74	170	<0.4	0.2	-	0.2	-	<0.01	0.15	<0.01	-	-	<0.02

Table E-2 (continued)
Summary of Groundwater Quality Laboratory Results (Deep Zone, Composite and Lower Aquifer)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Farmers Water District																									
R-10	5/27/2009	FGL	844	530	8.6	150	31	3	<1	195	2	77	109	190	<0.4	0.5	<2	0.5	-	<0.01	<0.05	<0.01	14	-	<0.02
R-10	5/27/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
R-10	5/17/2010	FGL	859	520	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R-10	8/15/2011	FGL	870	530	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R-10	5/9/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
R-10	5/9/2012	FGL	877	540	8.6	150	-	3	<1	198	2	87	125	180	<1.8	0.3	<2	0.5	-	<0.01	<0.05	<0.01	14	-	<0.02
R-10	5/7/2013	FGL	893	570	8.6	150	-	3	<1	197	2	80	131	190	<0.4	0.4	<2	0.5	-	<0.01	<0.05	<0.01	14	2.71	<0.02
R-10	5/20/2014	CAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	-
R-10	5/20/2014	FGL	896	550	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R-10	5/20/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
R-11	8/24/2000	FGL	808	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R-11	6/25/2001	FGL	739	470	8.6	150	22.1	2	<1	153	2	41	102	190	<0.1	0.4	<2	0.37	-	<0.01	0.09	<0.01	12	-	<0.02
R-11	6/25/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
R-11	6/25/2002	FGL	737	460	8.6	150	21	2	<1	146	2	34	106	190	<0.4	0.3	<2	0.4	-	<0.01	<0.05	<0.01	-	-	<0.02
R-11	6/25/2002	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.3	<0.4	-
R-11	8/20/2002	TL	540	330	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R-11	8/20/2002	CLS	520	320	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R-11	8/20/2002	FGL	535	370	8.7	140	-	<1	<1	115	<1	5	84	170	0.5	0.3	-	0.3	0.0041	<0.01	0.15	<0.01	-	-	<0.02
R-11	7/8/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.2	<0.4	-
R-11	10/26/2005	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11.4	<0.4	-
R-11	10/26/2005	FGL	803	500	8.6	160	-	2	<1	156	2	39	118	190	<0.4	0.5	<2	0.4	-	<0.01	0.08	<0.01	-	-	<0.02
R-11	5/15/2007	CLS	790	470	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R-11	9/17/2007	FGL	810	480	8.4	150	34.9	2	<1	179	1	49	118	160	3	0.4	<2	0.4	0.0093	<0.01	0.09	<0.01	-	-	<0.02
R-11	9/17/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11.1	<0.4	-
R-11	9/18/2008	FGL	859	490	8.5	160	28.1	3	<1	177	2	41	141	190	<0.4	0.3	<2	0.4	0.011	<0.01	0.07	<0.01	-	-	<0.02
R-11	9/18/2008	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11.93	<0.4	-
R-11	5/27/2009	FGL	870	490	8.6	170	31.6	3	<1	199	2	40	145	200	<0.4	0.4	<2	0.4	0.0111	<0.01	0.05	<0.01	9	-	<0.02
R-11	5/27/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
R-11	5/17/2010	FGL	1000	600	8.4	190	32.1	3	<1	202	2	40	167	240	<0.4	0.3	<2	0.3	0.0141	<0.01	0.06	<0.01	8	-	<0.02
R-11	5/17/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
R-11	7/22/2011	FGL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-
R-11	8/15/2011	FGL	1120	650	7.2	-	34.3	4	<1	249	2	16	180	330	<0.4	0.2	<2	0.3	0.0179	<0.01	0.09	0.01	-	-	<0.02
R-11	5/8/2012	FGL	1160	670	8.5	220	-	4	<1	261	3	41	215	270	<1.8	0.2	<2	0.4	0.0176	<0.01	<0.05	0.01	8	-	<0.02
R-11	5/8/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
R-11	5/7/2013	FGL	1220	750	8.6	230	-	5	<1	276	3	41	210	280	<0.4	0.2	<2	0.4	-	<0.01	<0.05	0.02	9	4.63	<0.02
R-11	5/20/2014	CAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	-
R-11	5/20/2014	FGL	1260	760	8.33	230	-	5	<1	260	3	41.1	236	280	<0.4	<0.1	<2	0.3	0.0241	<0.01	0.07	0.02	9	-	<0.02
R-11	5/20/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
R-12	5/20/2014	FGL	802	510	8.24	170	-	3	<1	170	2	80.1	97	210	<0.4	<0.1	<2	0.3	0.0128	<0.01	<0.05	0.01	9	-	<0.02
R-12	5/20/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
Baker Farming Co.																									
BF-1	8/25/1999	FGL	549	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BF-1	9/22/1999	FGL	686	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BF-1	10/1/2001	FGL	497	300	8.9	120	17.3	1	<1	102	<1	44	53	140	<0.4	0.2	<2	0.12	-	<0.01	0.08	<0.01	-	-	<0.02
BF-1	10/1/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.9	<0.4	-
BF-1	6/26/2002	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.9	<0.4	-

Table E-2 (continued)
Summary of Groundwater Quality Laboratory Results (Deep Zone, Composite and Lower Aquifer)

Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Cations				Anions					Trace Elements								
								Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
Baker Farming Co.																									
BF-5	10/1/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.8	<0.4	-
BF-5	5/16/2007	CLS	470	270	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BF-5	9/19/2008	FGL	467	290	8.4	100	15.1	3	<1	95	<1	37	53	120	<0.4	0.1	<2	<0.1	0.006	<0.01	<0.05	0.02	-	-	<0.02
BF-5	9/19/2008	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.85	<0.4	-
BF-5	5/18/2010	FGL	662	390	8.2	110	18	4	<1	131	2	73	82	140	<0.4	0.3	<2	0.3	-	<0.01	0.06	0.02	8	-	<0.02
BF-5	5/18/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
BF-5	5/20/2014	FGL	653	420	8.71	110	-	4	<1	128	2	72.1	85	140	<0.4	<0.1	<2	0.3	0.0144	<0.01	0.07	0.02	8	-	<0.02
BF-5	5/20/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
Panoche Creek Farms																									
PCF-1	6/25/2001	FGL	534	340	8.6	150	12.7	4	<1	110	1	38	51	180	<0.1	0.2	<2	0.15	-	<0.01	0.18	0.02	3	-	<0.02
PCF-1	6/25/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
PCF-1	10/1/2001	FGL	535	340	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PCF-1	10/1/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
PCF-1	6/26/2002	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.8	<0.4	-
PCF-1	6/26/2002	FGL	575	390	8.6	160	13	4	<1	112	1	37	57	190	<0.4	0.1	<2	0.2	-	<0.01	<0.05	0.02	-	-	<0.02
PCF-1	5/15/2007	CLS	630	400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PCF-1	9/17/2007	FGL	619	400	8.8	170	19.7	4	<1	143	<1	53	71	200	0.5	0.2	<2	0.2	-	<0.01	<0.05	0.02	-	-	<0.02
PCF-1	9/17/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7	<0.4	-
PCF-1	9/18/2008	FGL	633	410	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PCF-1	5/27/2009	FGL	676	430	8.5	170	25.8	3	<1	162	1	56	69	200	<0.4	0.3	<2	0.3	-	<0.01	<0.05	0.02	6	-	<0.02
PCF-1	5/27/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
PCF-1	5/17/2010	FGL	685	390	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PCF-1	5/9/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
PCF-1	5/9/2012	FGL	712	430	8.5	160	-	3	<1	162	1	67	80	200	<1.8	0.2	<2	0.2	-	<0.01	<0.05	0.02	6	-	<0.02
PCF-1	5/7/2013	FGL	701	450	8.3	180	-	3	<1	166	2	59	68	220	<0.4	0.1	<2	0.2	-	<0.01	<0.05	0.02	5	1	<0.02
PCF-1	5/20/2014	FGL	674	430	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

1. Laboratory Abbreviations: AT - Agri Tech, Inc., Kerman; BCL - BC Laboratories, Bakersfield; BD - Betz Dearborn; BSK - BSK Analytical Laboratories, Fresno; CAL - Caltest Analytical Laboratories, Napa; CLS - California Laboratory Services, Rancho Cordova; FGL - Fruit Growers Laboratory, Santa Paula; JML - JM Lord, Fresno; JML(1) - JM Lord, Fresno (TDS estimated from EC); OBL = Olson Biochemistry Laboratories of South Dakota State University, Brookings, SD; TL - The Twining Laboratories, Inc., Fresno.; UAG - U.S. Agricultural Consultants and Laboratories, Burbank; USGS - U.S. Geological Survey

2. Constituent Abbreviations: EC - Electrical Conductivity; TDS - Total Dissolved Solids; SAR - Sodium Absorption Ratio; Ca - Calcium; Mg - Magnesium; Na - Sodium; K - Potassium; SO4 - Sulfate; Cl - Chloride; HCO3 - Bicarbonate; NO3 - Nitrate; F - Fluoride; As - Arsenic; B - Boron; Ba - Barium; Cu - Copper; Fe - Iron; Mn - Manganese; Mo - Molybdenum; Se - Selenium; Zn - Zinc

3. Electrical Conductivity at 25°C

4. HCO3, Total Alkalinity and NO3 reported as HCO3, CaCO3 and NO3 respectively. Some 2008 NO3 results may include NO2 in reported value.

NA = Not Available; ND = Non Detect (detection limit unknown)

Table E-3
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
SHALLOW (Spreckels)																									
MW-1	8/2/1982	TL	-	-	-	-	-	8	2	370	9	99	255	470	<1	-	<10	0.5	-	-	0.06	0.03	-	-	-
MW-1	11/1/1982	BCL	1480	890	9.2	-	52	2.5	0.51	345	2	93	206	390	<0.4	0.84	<10	0.44	-	-	0.06	0.02	-	-	-
MW-1	11/24/1982	UNK	1480	890	9.2	-	-	2.5	0.5	345	2	93	206	389.8	-	0.84	-	0.44	-	-	0.06	0.02	-	-	-
MW-1	5/5/1983	BCL	1400	973	8.6	-	52.4	2.9	0.6	375	1.2	120	203	428	<0.1	-	<10	-	-	-	0.05	0.03	-	-	-
MW-1	12/3/1983	UNK	-	1128	8.4	-	-	4	8	370	-	85	196	240	-	-	-	-	-	-	0.17	0.02	-	-	-
MW-1	5/22/1984	BCL	1780	1083	8.8	-	50.2	3	1.1	400	0.9	145	230	424	<0.4	-	-	-	-	-	0.08	0.04	-	-	-
MW-1	11/27/1984	UNK	1450	1033	8.3	-	-	3.4	1.7	355	0.7	110	185	474	-	-	-	0.44	-	-	-	0.03	-	-	-
MW-1	11/1/1985	UNK	1380	865	8.6	-	-	2.3	0.9	327	0.5	88	174	402	-	-	-	-	-	-	0.06	0.02	-	-	-
MW-1	9/27/1986	UNK	1510	950	8.6	-	-	2.4	1	352	0.6	114	190	468	-	-	-	0.56	-	-	-	0.02	-	-	-
MW-1	4/21/1987	BCL	1530	935	7.8	-	47.9	2.4	1	350	0.7	101	192	473	0.4	-	-	-	<0.1	-	0.06	0.03	-	-	-
MW-1	3/28/1988	BCL	1280	830	8.9	-	45.7	1.9	0.9	305	0.7	85	153	345	<0.4	-	-	-	<0.1	-	<0.05	0.01	-	-	-
MW-1	12/22/1988	BCL	1330	925	8.8	-	49	2	1	340	1	136	230	282	<0.4	-	-	-	-	-	<0.05	0.01	-	-	-
MW-1	12/15/1989	UNK	1480	905	8.9	-	-	2.6	1.5	325	0.6	124	225	304	-	-	-	-	-	-	-	0.024	-	-	-
MW-1	4/11/1990	BCL	1510	940	8.9	-	43.5	2.6	1.4	350	5	134	257	291	<0.4	-	5	-	<0.1	-	<0.05	0.021	-	-	-
MW-1	11/13/1990	UNK	-	1110	8.7	-	-	-	-	-	0.6	-	302	284	-	-	-	-	-	-	-	0.023	-	-	-
MW-1	6/10/1991	BCL	2400	1320	8.8	-	-	-	-	-	0.8	-	384	406	-	-	-	-	<0.1	-	-	-	-	-	-
MW-1	10/28/1991	UNK	2500	1365	8.8	-	-	5.3	2.8	530	0.7	209	299	542	4	0.6	-	0.56	-	-	-	49	-	-	-
MW-1	2/24/1992	BCL	2700	1570	8.6	-	54	4.8	2.3	575	0.5	384	267	632	<0.4	0.66	-	0.56	<0.1	-	<0.05	0.024	-	-	-
MW-1	10/19/1992	BCL	3600	2110	8.5	-	58	8	4	805	1.7	355	380	948	3.1	0.64	-	0.63	<0.1	-	<0.05	0.036	-	-	-
MW-1	3/3/1993	BCL	3900	2270	8.5	-	60.4	8.7	5.2	912	2	310	344	1230	<0.4	0.55	-	0.8	<0.1	-	0.059	0.046	-	-	-
MW-1	9/20/1993	UNK	4000	2230	8.4	-	-	9.5	4.9	937	2.5	340	350	1310	4	0.64	-	0.94	-	-	-	0.045	-	-	-
MW-1	3/8/1994	BCL	4050	2580	8.4	-	68.8	7.6	5.1	999	2.1	450	444	1270	<0.4	0.74	-	0.45	0.2	-	4.15	2.32	-	-	-
MW-1	9/19/1994	BCL	4050	2630	8.4	-	59.3	10.5	5.4	948	2.6	505	438	1090	1.3	0.38	-	0.86	<0.1	-	<0.05	0.046	-	-	-
MW-1	3/15/1995	BCL	4000	2580	8.4	-	66.9	8.5	4.9	989	2.7	489	493	1100	5.8	0.44	-	0.86	<0.1	-	<0.05	0.021	-	-	-
MW-1	10/9/1995	UNK	4270	2690	8.3	-	-	10.9	6.5	1020	2.4	365	488	1430	4	0.72	-	1.2	-	-	-	0.032	-	-	-
MW-1	4/2/1996	BCL	4300	2590	8.4	-	56.1	11.5	7.4	992	2.6	440	520	1280	<0.4	0.6	-	1	<0.1	-	<0.05	0.085	-	-	-
MW-1	9/30/1996	BCL	3660	2300	9.0	-	59.4	8.2	5.6	901	2.2	336	445	1070	8.9	0.54	-	1	<0.1	-	<0.05	0.067	-	-	-
MW-1	6/2/1997	BCL	2340	1440	8.6	-	54.4	3.8	2.4	550	1.4	186	241	665	<0.4	0.59	-	0.84	<0.1	-	<0.05	0.037	-	-	-
MW-1	3/18/1998	BSK	3600	2200	8.3	1100	59.5	9	4.6	880	1.8	<50	410	1342	<25	<2.5	31	1.3	0.06	-	<0.05	0.07	-	2	-
MW-1	8/25/1998	BSK	3300	2000	8.4	960	57.3	7.8	3.8	780	2.4	210	390	1171	<2	<1	-	1.2	<0.05	-	<0.05	0.06	-	-	-
MW-1	4/20/1999	BSK	2800	1800	8.4	780	58.4	6.1	3.1	710	2	370	490	952	<6	<3	-	1	<0.05	-	<0.05	0.04	-	-	-
MW-1	11/14/1999	BSK	3800	2400	8.2	1400	55.8	10	5.1	870	2	190	430	1708	<10	<5	-	1.2	0.05	-	<0.05	0.08	-	-	-
MW-1	5/21/2000	BSK	3400	2200	8.2	1100	60.3	8.9	4.4	880	<2	210	400	1342	<8	<4	-	1.2	0.05	-	<0.05	0.07	-	-	-
MW-1	12/19/2000	BSK	3900	2500	8.2	1300	60.7	7.6	4	830	2	220	440	1586	<10	<5	-	1.2	<0.05	-	<0.05	0.06	-	-	-
MW-1	6/5/2001	BSK	3800	2600	8.1	1400	67.7	8.3	5	1000	2	200	490	1708	-	<5	-	1.3	<0.05	-	<0.05	0.08	-	-	-
MW-1	10/2/2001	UNK	4300	2200	8.0	1400	-	11	6.1	1100	ND	210	480	1400	ND	ND	-	1.3	0.06	-	ND	0.1	-	-	-
MW-1	5/2/2002	BSK	4100	2400	8.2	1500	-	7.4	4.4	980	2	180	500	1500	<12	<6	-	1.2	0.06	-	<0.05	0.08	-	-	-
MW-1	9/17/2002	TL	4400	2700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW-1	12/10/2002	BSK	4000	2500	8.2	1300	-	7.4	5.3	920	2	140	490	-	-	ND	-	1.2	0.06	-	ND	0.12	-	-	-
MW-1	1/13/2003	TL	4000	2500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW-1	3/23/2003	BSK	3800	2400	8.0	1200	-	7.2	5.3	920	<2	130	460	1460	<27	<3	-	1.1	0.06	-	0.06	0.12	-	-	-
MW-1	9/30/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	32	-	-	-	-	-	38.2	<0.4	-
MW-1	9/30/2003	TL	4000	2700	7.9	1400	-	7.2	5.7	1100	8.3	160	490	1700	<1.8	-	-	1.2	0.06	<0.05	<0.05	0.14	-	-	<0.05
MW-1	10/24/2003	BSK	4200	2700	8.3	1500	-	8.2	6.8	1000	3	180	490	-	-	ND	-	1.2	0.06	-	ND	0.14	-	-	-
MW-1	3/4/2004	TL	3800	2400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW-1	4/1/2004	UNK	3800	2400	8.2	1400	-	9	7	980	3	120	460	1400	ND	ND	-	1.1	0.06	-	ND	0.13	-	-	-
MW-1	11/14/2004	BSK	4000	2500	8.3	1500	-	9.5	8.8	920	3	120	470	1830	<9	<1	-	1.1	0.06	-	<0.05	0.15	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements									
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
SHALLOW (Spreckels)																										
MW-2	3/15/1995	UNK	2200	1350	7.4	-	-	0.79	0.4	395	10.8	36	240	1020	-	0.31	-	0.42	0.18	-	-	2.46	-	-	-
MW-2	10/17/1995	UNK	2190	2190	7.4	-	-	85	38	362	8.9	-	235	1080	-	0.27	-	0.45	0.161	-	-	2.48	-	-	-
MW-2	4/3/1996	UNK	2140	1200	7.4	-	-	94	45	346	7.2	-	210	210	-	0.29	-	0.42	0.154	-	-	2.72	-	-	-
MW-2	9/30/1996	UNK	2170	1300	8.1	-	-	86	44	374	6.2	-	217	1110	-	0.31	-	0.43	0.154	-	-	2.42	-	-	-
MW-2	6/2/1997	UNK	2140	1300	7.9	-	-	78	37	392	5.7	-	194	1110	-	0.37	-	-	0.132	-	-	2.19	-	-	-
MW-2	3/18/1998	UNK	2100	1300	7.5	-	-	81	35	400	5.8	-	180	930	-	-	-	0.43	0.15	-	-	2.1	-	-	-
MW-2	8/25/1998	UNK	2200	1300	7.4	-	-	84	35	380	6.9	ND	210	910	ND	ND	-	0.44	0.15	-	ND	2.3	-	-	-
MW-2	4/20/1999	BSK	2200	1300	7.3	930	8.2	110	44	400	8	<50	220	1135	<5	<2.5	-	0.4	0.18	-	<0.05	2.6	-	-	-
MW-2	11/15/1999	UNK	2300	1400	7.7	-	-	110	41	370	8	ND	230	900	ND	ND	-	0.4	0.19	-	ND	4.1	-	-	-
MW-2	5/21/2000	BSK	2100	1400	7.3	940	7.9	99	36	360	7	<50	220	1147	<5	<2.5	-	0.4	0.17	-	<0.05	2.6	-	-	-
MW-2	12/19/2000	BSK	2200	1300	7.3	980	8.7	85	32	370	7	<50	200	1196	<5	<2.5	-	0.4	0.15	-	<0.05	2.2	-	-	-
MW-2	6/5/2001	BSK	2200	1400	7.0	1000	8.3	100	41	390	9	<60	250	1220	-	<3	-	0.4	0.18	-	<0.05	3.5	-	-	-
MW-2	10/2/2001	UNK	2500	1400	7.1	1000	-	110	44	390	10	ND	230	1000	ND	ND	-	0.4	0.2	-	ND	3.4	-	-	-
MW-2	5/2/2002	BSK	2300	1400	7.6	950	-	94	35	350	6	<70	220	950	<7	<3.5	-	0.4	0.18	-	<0.05	2.7	-	-	-
MW-2	9/17/2002	TL	2400	1400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW-2	12/11/2002	BSK	2300	1400	7.4	910	-	74	29	360	4	ND	220	-	-	ND	-	0.4	0.16	-	ND	1.8	-	-	-
MW-2	1/13/2003	TL	2500	1500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW-2	3/23/2003	BSK	2400	1400	7.5	980	-	91	35	370	6	<40	240	1200	<18	<2	-	0.4	0.18	-	<0.05	2.6	-	-	-
MW-2	9/30/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	-	-	-	-	-	1.8	<0.4	-
MW-2	9/30/2003	TL	2400	1500	7.1	990	-	110	43	420	20	41	500	1200	<1.8	-	-	0.41	0.26	<0.05	6.4	3.1	-	-	<0.05
MW-2	10/24/2003	BSK	2300	1400	7.8	-	-	110	41	350	8	ND	230	-	-	ND	-	0.4	0.17	-	ND	2.9	-	-	-
MW-2	3/4/2004	TL	2400	1500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW-2	4/1/2004	UNK	2500	1600	7.7	1100	-	130	50	440	12	ND	290	1100	ND	ND	-	0.4	0.22	-	ND	3.6	-	-	-
MW-2	11/14/2004	BSK	2600	1600	7.7	1200	-	110	51	430	12	<2	280	1460	<4	0.7	-	0.4	0.21	-	<0.05	3.3	-	-	-
MW-2	3/2/2005	TL	2900	1700	-	-	-	-	-	-	-	-	-	-	-	-	-	0.4	-	-	-	3.8	<5	-	-
MW-2	4/7/2005	UNK	2800	1700	7.8	1200	-	120	53	430	14	ND	320	1200	ND	ND	-	0.4	0.23	-	ND	3.7	-	-	-
MW-2	8/9/2005	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	37	-	-	-	-	-	1.7	<0.4	-
MW-2	8/9/2005	TL	2500	1600	7.0	1100	-	120	53	430	23	<20	280	1400	<2	-	-	0.39	0.31	<0.005	9	3.5	-	-	<0.005
MW-2	10/13/2005	UNK	2700	1600	7.9	1100	-	120	55	450	12	ND	290	1100	ND	ND	-	0.5	0.23	-	ND	3.6	-	-	-
MW-2	4/20/2006	UNK	2772	1620	7.5	1161	-	115	50.8	399	17.6	ND	291	1161	ND	0.2	-	0.32	0.2	-	0.02	3.4	-	-	-
MW-2	4/20/2006	TL	2600	1700	7.2	1100	-	120	56	480	26	<2	280	-	<2	-	-	-	-	<0.01	9.5	3.4	-	-	<0.01
MW-2	9/26/2006	UNK	2902	1682	7.4	1160	-	122	54.4	452	15	ND	314	1160	ND	ND	-	0.43	0.2	-	0.02	3.56	-	-	-
MW-2	9/26/2006	TL	2700	1700	7.2	1100	-	130	58	430	26	<10	290	-	<10	-	42	0.41	0.32	<0.01	9.7	3.4	<10	<40	<0.01
MW-2	3/28/2007	TL	2700	1900	7.3	1100	-	120	55	440	24	ND	310	1300	-	-	25	0.42	0.33	ND	ND	3.1	ND	ND	0.028
MW-2	9/24/2007	TL	2600	1300	7.1	1100	-	110	53	440	25	-	240	1300	-	-	26	0.41	0.22	ND	8.7	2.9	-	-	ND
MW-2	9/24/2007	UNK	2500	1500	7.2	-	-	-	-	-	-	ND	250	1400	ND	-	-	-	-	-	-	-	-	-	-
MW-2	4/6/2008	BCL	2720	1700	7.36	-	-	-	-	-	-	6.6	290	1464	<0.4	-	-	-	-	-	-	-	-	-	-
MW-2	9/3/2008	BCL	2650	1600	7.4	-	-	-	-	-	-	<1	300	1342	<0.4	-	-	-	0.23	-	-	-	-	-	-
MW-2	4/2/2009	BCL	2500	1700	7.32	1100	-	120	56	460	12	2	290	1300	-	-	-	-	-	<0.002	8.4	3	-	-	<0.005
MW-2	4/2/2009	UNK	2590	1300	7.4	-	-	-	-	-	-	3	-	1100	ND	-	-	-	0.23	-	-	-	-	-	-
MW-2	10/2/2009	BSK	2600	1500	7.9	-	-	-	-	-	-	<20	280	1464	<10	-	-	-	-	-	-	-	-	-	-
MW-2	10/20/2009	BCL	2670	1500	7.53	1100	-	120	59	490	13	<2	300	1300	<0.9	-	29	0.45	0.3	<0.002	8.3	3.1	-	-	<0.005
MW-2	10/20/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.4	<0.4	-
MW-2	5/20/2010	BCL	2600	1400	7.46	1000	-	130	60	330	21	7.7	310	1200	<0.9	-	-	-	-	<0.002	10	3.4	-	-	0.0056
MW-2	9/15/2010	BCL	2610	1500	7.52	1000	-	120	56	450	15	6.5	320	-	1.7	-	37	0.42	0.33	<0.002	7.3	3.3	-	-	<0.005
MW-2	9/15/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.65	<0.4	-
MW-2	4/20/2011	BCL	2220	1500	7.36	920	-	100	48	410	11	4.2	270	1100	<0.4	-	-	-	-	<0.002	7.8	2.6	-	-	<0.005

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
SHALLOW (Spreckels)																									
MW-3	5/2/2002	BSK	2600	1400	7.3	1000	-	120	37	360	21	<80	270	1000	<8	<4	-	0.5	0.14	-	<0.05	1.7	-	-	-
MW-3	9/17/2002	TL	2700	1500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW-3	12/10/2002	BSK	2400	1500	7.6	960	-	82	25	380	13	ND	240	-	-	ND	-	0.5	0.1	-	ND	1.2	-	-	-
MW-3	1/13/2003	TL	2800	1700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW-3	3/23/2003	BSK	2600	1600	7.3	1000	-	110	33	380	19	<40	280	1220	<18	<2	-	0.4	0.15	-	<0.05	1.8	-	-	-
MW-3	9/29/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	82	-	-	-	-	-	11.1	<0.4	-
MW-3	9/29/2003	TL	3000	1800	6.9	1200	-	130	44	490	43	41	290	1500	<1.8	-	-	0.46	0.28	<0.05	25	2.1	-	-	<0.05
MW-3	10/24/2003	BSK	2800	1700	7.6	1300	-	130	43	400	27	ND	300	-	-	ND	-	0.4	0.11	-	ND	1.9	-	-	-
MW-3	3/4/2004	TL	2700	1700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW-3	4/1/2004	UNK	2600	1500	7.7	1100	-	110	39	430	25	ND	270	1100	ND	ND	-	0.5	0.14	-	ND	1.6	-	-	-
MW-3	11/14/2004	BSK	2500	1500	7.7	1100	-	92	35	420	22	29	240	1340	<4	0.7	-	0.5	0.1	-	<0.05	1.4	-	-	-
MW-3	3/2/2005	TL	1800	1000	-	-	-	-	-	-	-	-	-	-	-	-	-	0.47	-	-	-	0.8	<5	-	-
MW-3	4/7/2005	UNK	1800	970	7.8	670	-	48	16	290	20	35	180	670	ND	0.6	-	0.4	ND	-	ND	0.66	-	-	-
MW-3	8/9/2005	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	83	-	-	-	-	-	3.1	<0.4	-
MW-3	8/9/2005	TL	1300	850	7.2	540	-	36	11	270	26	29	150	660	<2	-	-	0.42	0.079	<0.005	5	0.54	-	-	<0.005
MW-3	10/13/2005	UNK	1600	920	8.0	640	-	42	14	280	17	ND	150	640	ND	ND	-	0.5	ND	-	ND	0.53	-	-	-
MW-3	4/20/2006	UNK	997	578	7.7	335	-	16.6	5.4	198	17.2	33	110	335	ND	0.7	-	0.33	0.01	-	0.08	0.22	-	-	-
MW-3	4/20/2006	TL	940	600	7.4	320	-	17	5.4	200	21	33	120	-	<2	-	-	-	-	<0.005	2.8	0.25	-	-	<0.005
MW-3	9/26/2006	UNK	1048	612	7.7	365	-	18.6	5.8	187	14.5	36	116	356	ND	0.4	-	0.33	0.01	-	0.04	0.27	-	-	-
MW-3	9/26/2006	TL	1000	630	7.4	350	-	20	6.3	190	22	36	100	-	<10	-	79	0.34	0.043	<0.005	2.9	0.29	<5	<20	<0.005
MW-3	3/28/2007	TL	930	550	7.5	250	-	16	5	170	19	62	110	310	-	-	60	0.34	0.079	ND	ND	0.18	8	ND	0.022
MW-3	9/24/2007	TL	1800	800	7.1	720	-	66	20	310	37	36	150	880	-	-	54	0.42	0.05	ND	11	0.79	-	-	ND
MW-3	9/24/2007	UNK	1700	1000	7.2	-	-	-	-	-	-	38	160	1700	ND	-	-	-	-	-	-	-	-	-	-
MW-3	4/6/2008	BCL	1560	930	7.53	-	-	-	-	-	-	22	150	793	<0.4	-	-	-	-	-	-	-	-	-	-
MW-3	9/3/2008	BCL	1640	940	7.4	-	-	-	-	-	-	32	160	781	0.2	-	-	-	0.042	-	-	-	-	-	-
MW-3	4/2/2009	BCL	1730	1100	7.33	640	-	74	23	330	25	88	180	790	-	-	-	-	-	<0.002	12	0.88	-	-	0.0069
MW-3	4/2/2009	UNK	1790	980	7.4	-	-	-	-	-	-	-	170	640	ND	-	-	-	0.067	-	-	-	-	-	-
MW-3	10/2/2009	BSK	1200	690	8.1	-	-	-	-	-	-	<10	120	610	<5	-	-	-	-	-	-	-	-	-	-
MW-3	10/20/2009	BCL	1260	740	7.73	470	-	32	10	240	17	8.2	130	570	<0.4	-	77	0.41	0.073	<0.002	4.6	0.4	-	-	0.0061
MW-3	10/20/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.7	<0.4	-
MW-3	5/20/2010	BCL	1950	1300	6.89	290	-	110	33	270	30	500	190	350	22	-	-	-	-	0.0031	12	1.9	-	-	0.021
MW-3	9/15/2010	BCL	906	660	7.69	290	-	17	5.7	180	10	54	85	360	-	-	47	0.34	0.037	<0.002	2.5	0.23	-	-	<0.005
MW-3	9/15/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.6	<0.4	-
MW-3	4/20/2011	BCL	996	640	7.43	220	-	27	8.5	200	14	130	110	260	<0.4	-	-	-	-	<0.002	4	0.33	-	-	0.0054
MW-3	9/1/2011	BCL	999	580	7.51	200	-	24	7.4	170	13	120	110	240	<0.4	-	34	0.35	0.04	<0.002	3	0.3	-	-	<0.005
MW-3	9/1/2011	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
MW-3	3/29/2012	BCL	852	580	7.51	180	-	23	7.3	130	11	89	97	232	<0.4	-	-	-	-	<0.002	3	0.28	-	-	<0.005
MW-3	10/4/2012	BCL	1100	680	7.47	240	-	37	11	180	14	140	120	293	<0.4	-	36	0.32	0.052	<0.002	4.8	0.45	11	-	<0.005
MW-3	10/4/2012	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
MW-3	5/7/2013	BCL	814	490	7.7	170	-	29	9.1	120	9.3	97	93	210	<0.4	-	-	-	-	0.00094	3.1	0.31	-	-	0.0038
MW-3	10/23/2013	BCL	1080	630	7.5	-	-	-	-	-	-	130	120	240	<0.4	-	-	-	-	-	-	-	-	-	-
MW-3	5/15/2014	BCL	1060	610	7.6	-	-	-	-	-	-	100	110	230	<0.4	-	-	-	-	-	-	-	-	-	-
MW-3	10/16/2014	BCL	1060	570	7.5	-	-	-	-	-	-	100	110	260	ND	-	-	-	-	-	-	-	-	-	-
MW-4	8/2/1982	TL	-	-	-	-	-	80	34	98	8	116	176	240	<1	-	<10	0.2	-	-	0.1	1.1	-	-	-
MW-4	11/24/1982	UNK	1020	630	7.6	-	-	67.5	34	96	8.3	128	152.2	207.9	-	0.08	-	0.09	-	-	2	0.94	-	-	-
MW-4	6/30/1983	UNK	950	560	7.4	-	-	60	31	98	6.8	115	147	215	1.8	-	-	-	-	-	3	0.92	-	-	-
MW-4	10/7/1983	UNK	970	610	7.1	-	-	70	36	95	7.5	124	145	244	5.8	-	-	-	-	-	1.9	0.83	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
SHALLOW (Spreckels)																									
MW-4	4/5/2008	BCL	2270	1400	7.39	-	-	-	-	-	-	96	310	842	1.4	-	-	-	-	-	-	-	-	-	-
MW-4	9/2/2008	BCL	2160	1200	7.4	-	-	-	-	-	-	100	330	805	1.5	-	-	-	0.14	-	-	-	-	-	-
MW-4	4/2/2009	UNK	2100	1100	7.4	-	-	-	-	-	-	79	310	640	4	-	-	-	0.13	-	-	-	-	-	-
MW-4	9/30/2009	BSK	2300	1300	8.1	-	-	-	-	-	-	97	340	903	<10	-	-	-	-	-	-	-	-	-	-
MW-4	10/19/2010	SSC	2300	1400	7.0	-	-	-	-	-	-	100	330	860	<2	-	-	-	-	-	-	-	-	-	-
MW-4	6/2/2011	SSC	2300	1300	7.1	-	-	-	-	-	-	120	310	670	<2.2	-	-	-	-	-	-	-	-	-	-
MW-4	10/3/2011	SSC	2100	1200	7.0	-	-	-	-	-	-	140	280	570	4.9	-	-	-	-	-	-	-	-	-	-
MW-4	3/29/2012	BCL	2010	1300	7.5	-	-	-	-	-	-	120	280	647	2.1	-	-	-	-	-	-	-	-	-	-
MW-4	10/4/2012	BCL	1910	1200	7.54	-	-	-	-	-	-	140	270	610	2.4	-	-	-	-	-	-	-	-	-	-
MW-4	5/6/2013	BCL	1700	1100	7.5	-	-	-	-	-	-	120	260	470	<0.9	-	-	-	-	-	-	-	-	-	-
MW-4	10/23/2013	BCL	1800	1100	7.6	-	-	-	-	-	-	130	260	440	<0.9	-	-	-	-	-	-	-	-	-	-
MW-4	5/15/2014	BCL	1860	1100	7.7	-	-	-	-	-	-	140	250	380	<0.9	-	-	-	-	-	-	-	-	-	-
MW-4	10/16/2014	BCL	1680	890	7.6	-	-	-	-	-	-	130	230	360	0.3	-	-	-	-	-	-	-	-	-	-
MW-5	8/3/1982	TL	-	-	-	-	-	86	41	74	7	119	142	280	<1	-	<10	0.2	-	-	0.47	0.92	-	-	-
MW-5	11/24/1982	UNK	980	590	7.3	-	-	79	43	66.5	6.9	114	125.7	270.3	-	-	-	0.04	-	-	1.5	0.86	-	-	-
MW-5	5/5/1983	UNK	820	587	7.6	-	-	46	41	59	5.4	94	109	210	-	-	-	-	-	-	1.4	0.85	-	-	-
MW-5	12/2/1983	UNK	810	470	8.0	-	-	61	33	56	6	85	95.9	229	-	-	-	-	-	-	0.3	0.57	-	-	-
MW-5	5/22/1984	UNK	1390	973	7.2	-	-	108	53	91	6.5	220	204	198	117.8	-	-	-	-	-	5.4	1.3	-	-	-
MW-5	7/19/1984	UNK	1160	750	7.6	-	-	97	44	76	5.7	165	158	220	74.4	-	-	-	-	-	0.11	0.09	-	-	-
MW-5	11/28/1984	UNK	930	663	7.5	-	-	78	38	63	5.1	115	121	225	58.9	-	-	0.04	-	-	-	0.06	-	-	-
MW-5	4/23/1985	UNK	1000	727	7.3	-	-	76	41	70	4.9	120	131	250	62.9	-	-	-	-	-	-	0.26	-	-	-
MW-5	11/4/1985	UNK	1250	795	7.2	-	-	96	47	97	6.1	156	183	257	156.7	-	-	-	-	-	0.14	0.04	-	-	-
MW-5	9/23/1986	UNK	1900	1215	7.6	-	-	130	62	191	6.9	271	275	374	166.9	-	-	-	-	-	0.52	0.07	-	-	-
MW-5	4/21/1987	UNK	1290	845	7.5	-	-	93	46	119	5.7	160	177	328	58.9	-	-	-	-	-	0.17	0.11	-	-	-
MW-5	3/24/1988	UNK	1620	1015	7.3	-	-	102	47	205	608	118	236	520	46.9	-	-	-	-	-	0.1	0.06	-	-	-
MW-5	12/16/1988	UNK	860	525	7.9	-	-	49	30	94	4.3	86	118	243	12	-	-	-	-	-	-	0.04	-	-	-
MW-5	12/22/1988	BCL	860	525	7.9	-	2.6	49	30	94	4	86	118	243	3	-	-	-	<0.1	-	<0.05	0.04	-	-	-
MW-5	12/13/1989	UNK	1100	655	7.5	-	-	48	22	153	4.2	82	155	300	29.2	-	-	-	-	-	0.118	0.065	-	-	-
MW-5	11/14/1990	UNK	-	375	7.5	-	-	-	-	-	2.4	-	84.7	186	-	-	-	-	-	-	-	0.03	-	-	-
MW-5	6/20/1991	UNK	1510	980	7.4	-	-	-	-	-	4.6	-	227	514	-	-	-	-	-	-	-	-	-	-	-
MW-5	10/29/1991	UNK	1260	775	7.4	-	-	88	45	108	4.8	151	183	310	-	0.11	-	0.11	0.105	-	-	0.192	-	-	-
MW-5	2/24/1992	UNK	1300	835	7.3	-	-	110	51	88	5.5	160	193	301	-	0.06	-	0.11	0.125	-	0.158	0.92	-	-	-
MW-5	10/20/1992	UNK	1460	920	7.2	-	-	106	46	135	5.7	139	211	373	-	0.11	-	0.19	0.141	-	0.181	0.631	-	-	-
MW-5	3/1/1993	UNK	1130	680	7.2	-	-	126	53	89	5.4	186	227	283	-	0.12	-	0.18	0.167	-	0.522	1.18	-	-	-
MW-5	9/27/1993	UNK	1740	1500	7.6	-	-	43	20	316	4.2	60	270	517	68.6	0.22	-	0.2	0.102	-	0.082	0.151	-	-	-
MW-5	3/10/1994	UNK	1700	985	7.5	-	-	39	19	314	4	60	258	489	49.1	0.24	-	0.24	-	-	0.056	0.111	-	-	-
MW-5	9/20/1994	UNK	1250	800	7.1	-	-	94	42	104	6.9	109	156	367	-	0.07	-	0.12	0.14	-	-	0.74	-	-	-
MW-5	3/16/1995	UNK	1450	900	6.9	-	-	116	49	121	6.8	188	201	357	-	0.07	-	0.12	0.196	-	-	1.05	-	-	-
MW-5	10/10/1995	UNK	1680	860	7.7	-	-	39	17.5	306	4	33	252	556	12	0.25	-	0.28	-	-	-	-	-	-	-
MW-5	4/6/1996	UNK	2000	1210	7.3	-	-	84	51	283	9.6	434	258	321	-	0.08	-	-	-	-	-	2.3	-	-	-
MW-5	9/30/1996	UNK	1510	885	8.3	-	-	69	36	192	5.9	94	228	432	1.8	0.11	-	0.22	0.102	-	-	0.438	-	-	-
MW-5	6/30/1997	UNK	1650	970	7.8	-	-	98	46	186	5.9	243	-	484	5.3	0.1	-	0.22	0.116	-	-	0.414	-	-	-
MW-5	3/20/1998	UNK	1400	950	7.3	-	-	95	40	260	8.2	120	270	400	-	-	-	0.21	0.13	-	-	0.03	-	-	-
MW-5	8/26/1998	UNK	1800	1100	7.3	-	-	110	48	220	5.5	190	250	360	ND	ND	-	0.21	0.15	-	ND	0.23	-	-	-
MW-5	4/22/1999	BSK	1700	1000	7.7	440	7.1	72	34	290	6	67	260	537	<4	<2	-	0.2	0.09	-	<0.05	0.09	-	-	-
MW-5	5/21/2000	BSK	1600	1000	7.2	470	7.3	61	31	280	5	67	290	573	6.4	<2	-	0.2	0.1	-	<0.05	0.41	-	-	-
MW-5	12/17/2000	BSK	1700	996	7.2	440	7.2	61	32	280	5	50	280	537	<4	<2	-	0.2	0.11	-	<0.05	0.56	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
SHALLOW (Spreckels)																									
MW-6	10/20/1992	UNK	1450	940	7.0	-	-	100	40	138	6.6	167	221	295	-	-	-	0.25	0.102	-	8.11	1.4	-	-	-
MW-6	3/1/1993	UNK	1600	1060	7.0	-	-	117	48	154	6.5	185	262	354	-	0.07	-	0.26	0.13	-	9.95	1.84	-	-	-
MW-6	9/27/1993	UNK	1560	1010	7.0	-	-	102	47	164	7.1	162	241	394	-	0.06	-	0.14	0.165	-	10.4	1.53	-	-	-
MW-6	3/10/1994	UNK	1660	1060	7.1	-	-	104	47	169	7.1	191	248	356	-	0.05	-	0.21	0.154	-	8.4	1.51	-	-	-
MW-6	9/20/1994	UNK	1770	1170	7.0	-	-	121	51	173	7.2	220	258	362	-	0.05	-	0.2	0.16	-	-	2.12	-	-	-
MW-6	3/16/1995	UNK	1640	1030	6.9	-	-	116	47	159	7.3	216	247	346	-	0.05	-	0.16	-	-	-	1.93	-	-	-
MW-6	10/10/1995	UNK	1680	1020	7.0	-	-	122	51	146	6.9	213	257	357	-	-	-	0.25	-	-	-	2	-	-	-
MW-6	4/6/1996	UNK	1830	1160	7.0	-	-	144	54	154	6.8	263	274	352	-	-	-	0.23	0.1	-	0.205	2.82	-	-	-
MW-6	9/30/1996	UNK	1730	1080	8.4	-	-	118	55	152	7.4	202	282	348	-	-	-	0.22	-	-	-	2.21	-	-	-
MW-6	6/30/1997	UNK	1730	1050	7.0	-	-	123	55	140	6.7	222	284	310	-	0.05	-	0.22	-	-	2.02	2.5	-	-	-
MW-6	3/20/1998	UNK	1300	970	7.0	-	-	130	47	160	9.5	200	250	240	-	-	-	-	-	-	-	2.6	-	-	-
MW-6	8/26/1998	UNK	1700	1000	6.8	-	-	120	48	180	7.5	190	290	230	ND	ND	-	0.14	0.08	-	1.5	2.9	-	-	-
MW-6	4/21/1999	BSK	1700	1100	7.0	250	3.1	130	58	170	9	220	280	305	<4	<2	-	0.1	0.06	-	0.05	2.7	-	-	-
MW-6	5/21/2000	BSK	1400	900	6.6	240	3.2	88	48	150	8	190	220	293	<3	<1.5	-	0.1	<0.05	-	1.4	1.6	-	-	-
MW-6	12/17/2000	BSK	1400	880	6.4	230	3	90	44	140	7	190	210	281	<4	<2	-	0.1	0.05	-	0.75	1.6	-	-	-
MW-6	6/5/2001	BSK	1300	830	6.8	240	3.2	90	45	150	8	200	210	293	-	<1.5	-	0.2	0.05	-	0.43	1.8	-	-	-
MW-6	10/3/2001	UNK	1400	890	6.4	-	-	88	43	150	6	160	210	240	ND	ND	-	0.1	0.05	-	0.65	1.5	-	-	-
MW-6	5/2/2002	BSK	1300	900	6.8	240	-	74	37	130	6	170	180	240	<4	<2	-	0.2	<0.05	-	1.3	1.4	-	-	-
MW-6	12/11/2002	BSK	1500	870	7.0	260	-	73	34	160	6	180	230	-	-	ND	-	0.2	ND	-	0.33	1.3	-	-	-
MW-6	3/22/2003	BSK	1500	900	6.9	250	-	76	34	150	-	190	220	-	-	ND	-	0.2	ND	-	0.62	-	-	-	-
MW-6	10/24/2003	BSK	1600	1000	7.6	310	-	98	44	180	7	160	250	-	-	ND	-	0.2	0.05	-	0.56	1.5	-	-	-
MW-6	4/1/2004	UNK	1600	970	7.6	300	-	94	39	190	7	170	240	300	ND	ND	-	0.2	0.06	-	0.45	1.4	-	-	-
MW-6	11/13/2004	BSK	1400	880	7.6	290	-	71	34	190	7	140	160	350	<2.7	<0.3	-	0.2	0.06	-	0.99	1.1	-	-	-
MW-6	4/6/2005	UNK	1500	900	7.7	290	-	91	36	200	7	180	240	290	ND	ND	-	0.2	0.06	-	0.37	1.4	-	-	-
MW-6	10/14/2005	UNK	2000	1200	7.9	300	-	120	53	220	8	240	320	300	ND	ND	-	0.2	0.07	-	1.9	2.1	-	-	-
MW-6	4/19/2006	DL	1705	1103	7.2	313	-	114	46	185	10.2	197	287	313	<0.1	<0.1	-	0.14	0.06	-	1.51	2.15	-	-	-
MW-6	9/25/2006	UNK	1887	1390	6.9	380	-	122	55.7	234	9.6	248	440	380	ND	ND	-	0.17	0.07	-	2.43	2.34	-	-	-
MW-6	3/29/2007	TL	2100	1300	7.0	410	-	120	56	260	18	170	360	500	<10.2	<0.5	<10	0.21	0.078	<0.005	-	-	<5	-	<0.005
MW-6	9/23/2007	TL	2000	1200	6.9	-	-	-	-	-	-	130	320	510	<20	-	-	-	-	-	-	-	-	-	-
MW-6	9/4/2008	BCL	2070	1300	7.2	-	-	-	-	-	-	130	310	549	<0.4	-	-	-	0.078	-	-	-	-	-	-
MW-6	4/3/2009	UNK	2020	1300	7.2	-	-	-	-	-	-	160	380	420	ND	-	-	-	0.08	-	-	-	-	-	-
MW-6	9/30/2009	BSK	2400	1400	8.0	-	-	-	-	-	-	210	460	537	<10	-	-	-	-	-	-	-	-	-	-
MW-6	10/6/2010	SSC	2300	1300	6.9	-	-	-	-	-	-	200	360	520	<2	-	-	-	-	-	-	-	-	-	-
MW-6	5/19/2011	SSC	2400	1400	6.9	-	-	-	-	-	-	230	400	420	<2.2	-	-	-	-	-	-	-	-	-	-
MW-6	9/21/2011	SSC	2500	1500	6.8	-	-	-	-	-	-	240	430	440	<2.2	-	-	-	-	-	-	-	-	-	-
MW-6	3/30/2012	BCL	2360	1400	7.39	-	-	-	-	-	-	210	380	512	<0.9	-	-	-	-	-	-	-	-	-	-
MW-6	10/4/2012	BCL	2250	1500	7.34	-	-	-	-	-	-	220	380	598	<0.9	-	-	-	-	-	-	-	-	-	-
MW-6	5/6/2013	BCL	2260	1500	7.3	-	-	-	-	-	-	200	370	510	<0.9	-	-	-	-	-	-	-	-	-	-
MW-6	10/23/2013	BCL	2450	1500	7.5	-	-	-	-	-	-	190	400	540	<2.2	-	-	-	-	-	-	-	-	-	-
MW-6	5/15/2014	BCL	2670	1600	7.5	-	-	-	-	-	-	190	400	560	<2.2	-	-	-	-	-	-	-	-	-	-
MW-6	10/16/2014	BCL	2720	1400	7.3	-	-	-	-	-	-	210	470	550	ND	-	-	-	-	-	-	-	-	-	-
MW-9	4/7/1984	UNK	950	513	6.9	-	-	75	40	55	6	35	115	333	-	-	-	0.1	-	-	15.4	2.2	-	-	-
MW-9	7/19/1984	UNK	900	550	7.3	-	-	74	33	55	5.9	50	104	294	-	-	-	-	-	-	9.4	1.9	-	-	-
MW-9	11/28/1984	UNK	1050	670	7.0	-	-	78	44	60	6.1	18	131	380	-	-	-	0.1	-	-	0.86	2.6	-	-	-
MW-9	4/24/1985	UNK	1160	740	7.2	-	-	92	50	74	6	21	146	454	-	-	-	-	-	-	-	2.6	-	-	-
MW-9	11/5/1985	UNK	1390	850	7.0	-	-	105	52	73	6.9	6	144	533	-	-	-	-	-	-	16.8	3.1	-	-	-
MW-9	9/24/1986	UNK	1050	620	7.3	-	-	95	44	67	6.3	45	121	439	-	-	-	-	-	-	11.3	2.3	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
SHALLOW (Spreckels)																									
MW-9	10/16/2014	BCL	1060	660	7.2	-	-	-	-	-	-	180	110	190	ND	-	-	-	-	-	-	-	-	-	-
MW-13	4/7/1984	UNK	1770	1043	7.8	-	-	15	14	365	4.8	10	128	840	-	-	-	0.41	-	-	0.67	0.88	-	-	-
MW-13	7/19/1984	UNK	1690	1040	7.4	-	-	14	12.4	350	7.1	13	126	809	-	-	-	-	-	-	0.58	0.86	-	-	-
MW-13	11/28/1984	UNK	1540	983	7.9	-	-	16	14	320	5.2	20	122	751	-	-	-	0.28	-	-	0.65	0.78	-	-	-
MW-13	4/24/1985	UNK	1550	1033	7.9	-	-	34	15	320	5.1	16	124	793	-	-	-	-	-	-	-	0.83	-	-	-
MW-13	11/5/1985	UNK	1540	1110	7.7	-	-	40	15	320	5.3	17	129	806	4	-	-	-	-	-	0.66	1	-	-	-
MW-13	9/24/1986	UNK	1610	1010	8.1	-	-	43	17	327	5.3	30	148	786	8	-	-	-	-	-	0.63	1	-	-	-
MW-13	4/22/1987	UNK	1600	1060	8.0	-	-	29	17	325	5.2	17	132	812	5.8	-	-	-	-	-	-	0.01	-	-	-
MW-13	3/24/1988	UNK	1580	1015	7.7	-	-	33	14	343	5.4	14	128	836	-	-	-	-	-	-	0.05	0.47	-	-	-
MW-13	12/19/1988	UNK	1310	945	7.6	-	-	12	4.7	320	3.6	30	138	643	8	-	-	-	-	-	0.22	0.27	-	-	-
MW-13	12/14/1989	UNK	1700	1060	7.8	-	-	33	12	350	4.3	82	207	633	-	-	-	-	-	-	0.49	0.695	-	-	-
MW-13	4/11/1990	UNK	1760	1125	7.8	-	-	39	16	360	4.8	82	236	638	1.8	-	-	-	-	-	0.625	0.891	-	-	-
MW-13	11/15/1990	UNK	-	1120	7.4	-	-	-	-	-	2.6	-	244	485	-	-	-	-	0.105	-	0.522	0.984	-	-	-
MW-13	6/20/1991	UNK	2400	1370	7.5	-	-	-	-	-	5.4	-	301	810	-	-	-	-	0.131	-	-	-	-	-	-
MW-13	10/29/1991	UNK	2400	1310	7.8	-	-	49	19	435	5.1	74	306	797	-	0.05	-	0.24	0.136	-	0.816	1.26	-	-	-
MW-13	2/24/1992	UNK	2400	1320	7.8	-	-	53	22	420	5.8	75	326	805	-	0.06	-	0.26	0.146	-	1.09	1.48	-	-	-
MW-13	10/20/1992	UNK	2400	1380	7.0	-	-	25	19.7	445	5.6	70	321	772	-	-	-	0.24	0.155	-	1.25	1.64	-	-	-
MW-13	3/1/1993	UNK	-	1330	7.4	-	-	64	25	387	5.4	85	315	778	-	0.05	-	0.27	0.179	-	1.66	2.05	-	-	-
MW-13	9/22/1993	BCL	3000	1240	7.3	-	9.7	69	26	371	6.1	65	300	-	-	-	-	-	-	-	-	-	-	-	-
MW-13	9/27/1993	UNK	-	1240	7.3	-	-	69	26	371	6.1	65	300	780	-	-	-	0.24	0.196	-	1.7	2.27	-	-	-
MW-13	3/10/1994	UNK	2140	1280	7.3	-	-	77	31	349	6.1	85	290	728	-	-	-	0.26	0.226	-	2.32	2.61	-	-	-
MW-13	9/20/1994	UNK	2120	1260	7.2	-	-	76	32	343	6.1	80	288	728	-	-	-	0.24	0.2	-	0.32	2.67	-	-	-
MW-13	3/16/1995	UNK	2200	1390	7.1	-	-	93	40	367	6.9	122	313	768	-	-	-	0.25	0.231	-	-	3.43	-	-	-
MW-13	10/10/1995	UNK	2570	1540	7.2	-	-	113	45	381	6.8	84	369	831	-	-	-	0.33	0.29	-	-	4.06	-	-	-
MW-13	4/6/1996	UNK	2800	1610	7.2	-	-	114	52	432	8	80	410	1020	-	-	-	0.31	0.296	-	-	-	-	-	-
MW-13	6/10/1996	UNK	2930	1690	8.2	-	-	105	50	484	10	48	436	1090	-	-	-	0.34	0.341	-	0.083	4.18	-	-	-
MW-13	6/3/1997	UNK	2740	1640	7.2	-	-	96	47	449	6.4	82.4	384	1000	-	-	-	0.33	0.292	-	-	3.85	-	-	-
MW-13	3/23/1998	UNK	2700	1900	7.0	-	-	120	57	580	10	69	470	970	-	-	-	0.28	0.44	-	-	3.4	-	-	-
MW-13	8/26/1998	UNK	3200	1800	7.3	-	-	120	55	510	7.7	73	490	900	10.2	ND	-	0.26	0.39	-	ND	4.3	-	-	-
MW-13	4/21/1999	BSK	3000	1800	7.5	1000	9.8	130	60	540	9	62	390	1220	<6	<3	-	0.2	0.41	-	<0.05	4	-	-	-
MW-13	5/20/2000	BSK	2500	1600	7.0	870	9.1	94	42	420	8	75	370	1061	6.3	<3	-	0.3	0.24	-	0.07	2.4	-	-	-
MW-13	12/17/2000	BSK	2400	1500	7.3	760	8.6	84	38	380	7	70	370	930	<5	<2.5	-	0.3	0.22	-	<0.05	2.2	-	-	-
MW-13	6/5/2001	BSK	2200	1700	7.3	560	7.8	87	40	350	8	100	380	683	<5	<2.5	-	0.2	0.18	-	<0.05	2.6	-	-	-
MW-13	10/3/2001	UNK	2400	1400	6.9	-	-	91	43	380	7	86	390	640	ND	ND	-	0.2	0.18	-	ND	2.4	-	-	-
MW-13	5/2/2002	BSK	2400	1400	7.6	600	-	81	38	360	6	100	380	600	<8	<4	-	0.2	0.18	-	<0.05	2.1	-	-	-
MW-13	12/10/2002	BSK	2100	1200	7.3	520	-	74	32	300	5	84	320	-	-	ND	-	0.2	0.15	-	ND	2	-	-	-
MW-13	3/22/2003	BSK	2200	1300	7.5	550	-	72	30	320	4	74	360	-	-	ND	-	0.3	0.16	-	ND	2	-	-	-
MW-13	9/30/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<3	-	-	-	-	-	2	<0.4	-
MW-13	9/30/2003	TL	2500	1400	7.0	190	-	90	40	430	17	64	400	230	<1.8	-	-	0.24	0.2	<0.05	1.6	2.2	-	-	<0.05
MW-13	10/24/2003	BSK	2500	1400	-	720	-	88	40	360	8	ND	400	-	-	ND	-	0.2	0.18	-	ND	2.2	-	-	-
MW-13	3/31/2004	BSK	2200	1400	7.7	630	-	85	39	400	6	96	400	770	<0.9	<0.1	-	0.2	0.2	-	0.06	2.2	-	-	-
MW-13	4/1/2004	TL	2300	1400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW-13	11/13/2004	BSK	2400	1500	7.9	820	-	71	36	450	7	36	370	1000	<4	<0.5	-	0.3	0.21	-	<0.05	1.9	-	-	-
MW-13	3/8/2005	TL	3200	1900	-	-	-	-	-	-	-	-	-	-	-	-	-	0.28	-	-	-	2.9	<25	-	-
MW-13	4/6/2005	UNK	2800	1700	7.8	800	-	92	49	500	8	100	490	800	ND	ND	-	0.3	0.28	-	ND	2.7	-	-	-
MW-13	8/11/2005	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<6	-	-	-	-	-	5.6	<0.4	-
MW-13	8/11/2005	TL	1300	890	7.2	250	-	27	15	270	8.7	120	220	310	4.6	-	-	0.23	0.081	<0.005	0.29	0.76	-	-	<0.005

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
SHALLOW (Spreckels)																									
MW-15	6/6/2001	BSK	6400	3500	7.6	2600	26.4	12	18	620	880	<200	560	3172	-	<10	-	0.4	0.44	-	1.8	0.03	-	-	-
MW-15	10/3/2001	UNK	6000	3000	7.4	-	-	8.6	20	520	750	ND	410	2400	ND	ND	-	0.4	0.39	-	0.5	0.03	-	-	-
MW-15	5/2/2002	BSK	6600	3500	7.8	2700	-	7.3	19	510	640	<20	59	2700	2.4	<1	-	0.3	0.5	-	0.72	0.02	-	-	-
MW-15	12/10/2002	BSK	6000	3200	7.8	2200	-	7.3	19	450	610	ND	440	-	-	ND	-	0.3	0.44	-	0.9	0.02	-	-	-
MW-15	3/22/2003	BSK	6200	3400	7.9	2200	-	9.5	19	500	670	180	490	-	-	ND	-	0.3	0.32	-	0.46	0.02	-	-	-
MW-15	10/25/2003	BSK	5400	2900	8.0	2100	-	15	37	470	650	140	350	-	-	ND	-	0.3	0.21	-	-	0.03	-	-	-
MW-15	3/31/2004	BSK	4800	2700	7.9	2200	-	16	38	490	610	140	320	2680	<0.9	<0.1	-	0.4	0.33	-	0.47	0.03	-	-	-
MW-15	11/14/2004	BSK	6100	3600	8.0	2400	-	20	24	620	860	280	420	2930	<18	<2	-	0.4	<0.1	-	0.27	0.09	-	-	-
MW-15	4/6/2005	UNK	8800	5800	8.0	2400	-	69	20	950	1500	1400	770	2400	53.1	ND	-	0.4	ND	-	0.1	0.05	-	-	-
MW-15	10/13/2005	UNK	9900	6000	7.9	1700	-	180	36	980	1600	2400	710	1700	ND	ND	-	ND	ND	-	ND	0.26	-	-	-
MW-15	4/19/2006	DL	11060	7823	7.6	1265	-	406	86	1689	2486	3301	776	1265	0.3	<0.1	-	0.18	0.05	-	0.02	0.37	-	-	-
MW-15	9/25/2006	UNK	13330	8087	7.2	1104	-	333	59.9	835	1331	3996	912	1104	447.1	ND	-	0.27	0.05	-	0.01	0.42	-	12	-
MW-15	3/28/2007	NA	11000	8800	7.1	960	-	430	52	980	1600	3000	710	1200	460	<5	-	0.3	0.11	-	-	-	-	-	-
MW-15	9/24/2007	TL	9000	6600	7.1	-	-	-	-	-	-	2500	530	1600	250	-	-	-	-	-	-	-	-	-	-
MW-15	4/5/2008	BCL	8110	6300	7.56	-	-	-	-	-	-	1500	690	2440	11.1	-	-	-	-	-	-	-	-	-	-
MW-15	9/2/2008	BCL	8160	5600	7.3	-	-	-	-	-	-	2100	580	1708	154.9	-	-	-	0.039	-	-	-	-	-	-
MW-15	4/3/2009	BCL	7320	5700	7.3	-	-	-	-	-	-	1800	580	1300	172.7	-	-	-	-	-	-	-	-	-	-
MW-15	4/3/2009	UNK	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05	-	-	-	-	-	-
MW-15	10/1/2009	BSK	7700	4400	7.8	-	-	-	-	-	-	1700	560	1952	53	-	-	-	-	-	-	-	-	-	-
MW-15	5/4/2011	SSC	13000	9900	6.9	-	-	-	-	-	-	2900	990	680	1239.6	-	-	-	-	-	-	-	-	-	-
MW-15	7/12/2011	SSC	5600	3900	7.1	-	-	-	-	-	-	640	620	480	841.1	-	-	-	-	-	-	-	-	-	-
MW-15	9/12/2011	SSC	3200	2100	7.4	-	-	-	-	-	-	320	260	540	296.6	-	-	-	-	-	-	-	-	-	-
MW-15	3/29/2012	BCL	2200	1600	7.77	-	-	-	-	-	-	170	180	647	100	-	-	-	-	-	-	-	-	-	-
MW-15	10/4/2012	BCL	1900	1300	7.91	-	-	-	-	-	-	120	130	610	93	-	-	-	-	-	-	-	-	-	-
MW-15	5/6/2013	BCL	1950	1300	7.8	-	-	-	-	-	-	130	160	480	110	-	-	-	-	-	-	-	-	-	-
MW-15	10/24/2013	BCL	2440	1600	7.9	-	-	-	-	-	-	270	200	620	48	-	-	-	-	-	-	-	-	-	-
MW-15	5/15/2014	BCL	3240	2000	7.9	-	-	-	-	-	-	420	250	690	7.5	-	-	-	-	-	-	-	-	-	-
MW-15	10/16/2014	BCL	2490	1600	7.8	-	-	-	-	-	-	190	220	690	5.8	-	-	-	-	-	-	-	-	-	-
MW-17	12/8/1988	BCL	5000	2534	7.5	-	9.7	53	62	440	512	50	241	2694	4	0.2	20	0.3	0.5	-	0.18	0.17	-	<5	-
MW-17	12/20/1988	UNK	2400	1190	7.5	-	-	15	16	215	240	21	120	1409	-	-	-	-	-	-	-	0.02	-	-	-
MW-17	12/8/1989	UNK	3300	1705	7.7	-	-	100	83	257	171	50	163	1580	4	-	-	-	-	-	0.104	0.136	-	-	-
MW-17	4/10/1990	UNK	3000	1825	7.7	-	-	90	70	280	200	35	148	1709	4	-	-	-	-	-	0.421	0.12	-	-	-
MW-17	5/21/1990	UNK	-	2135	-	-	-	-	-	-	189	-	136	1134	-	-	-	-	-	-	-	-	-	-	-
MW-17	11/16/1990	UNK	-	1910	7.2	-	-	-	-	-	270	-	466	1190	-	-	-	-	0.26	-	6.21	0.112	-	-	-
MW-17	6/18/1991	UNK	3600	1900	7.4	-	-	-	-	-	194	-	227	430	-	-	-	-	0.312	-	-	-	-	-	-
MW-17	10/22/1991	UNK	4100	1985	7.2	-	-	181	83	346	206	10	229	2160	-	0.1	-	0.26	0.321	-	7.26	0.199	-	-	-
MW-17	2/25/1992	UNK	3900	2300	7.5	-	-	175	86	350	197	16	227	2120	-	0.11	-	0.27	0.342	-	8.36	0.199	-	-	-
MW-17	10/23/1992	UNK	3000	1750	7.1	-	-	160	81	268	158	-	183	1600	-	0.08	-	0.24	0.267	-	9.8	0.216	-	-	-
MW-17	3/9/1993	UNK	3700	1810	7.2	-	-	181	95	329	184	-	194	2040	-	0.09	-	0.39	0.297	-	12.1	0.257	-	-	-
MW-17	9/23/1993	UNK	3600	1840	7.2	-	-	164	95	290	184	5	204	1980	-	0.09	-	0.22	0.32	-	10.6	0.261	-	-	-
MW-17	3/14/1994	UNK	3010	1610	7.2	-	-	140	80	281	162	-	195	1670	-	0.07	-	0.27	0.275	-	9.37	0.295	-	-	-
MW-17	10/3/1994	UNK	2900	1470	7.2	-	-	128	67	270	141	3	201	1580	-	0.08	-	0.24	0.51	-	8.71	0.31	-	-	-
MW-17	10/16/1995	UNK	3000	1550	7.4	-	-	124	65	285	136	75	212	1450	-	0.08	-	0.34	0.17	-	0.079	0.25	-	-	-
MW-17	4/8/1996	UNK	2860	1350	8.2	-	-	128	69	307	129	80	240	1490	-	0.08	-	0.4	0.149	-	0.107	0.97	-	-	-
MW-17	10/4/1996	UNK	3440	1820	8.1	-	-	156	81	368	149	32	238	1910	-	0.08	-	0.41	0.264	-	0.054	0.253	-	-	-
MW-17	6/5/1997	UNK	4410	2440	7.4	-	-	164	95	407	295	24.9	264	2490	-	0.13	-	0.49	0.238	-	0.101	0.267	-	-	-
MW-17	8/26/1998	UNK	3800	1800	7.1	-	-	230	160	380	140	100	240	ND	35	ND	-	0.33	0.23	-	0.11	0.5	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Cations				Anions					Trace Elements								
								Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
SHALLOW (Spreckels)																									
MW-18	10/4/1996	UNK	8030	4640	8.7	-	-	25	46	1460	415	6.2	920	3680	-	0.07	-	0.65	0.837	-	0.475	0.146	-	-	-
MW-18	6/4/1997	UNK	7980	4700	7.5	-	-	40	64	1360	408	6.8	916	3830	-	0.07	-	0.64	0.894	-	0.435	0.275	-	-	-
MW-18	3/24/1998	UNK	7400	4600	7.4	-	-	45	79	1400	450	-	910	3100	1.3	-	-	0.5	1.1	-	0.43	0.31	-	-	-
MW-18	8/25/1998	UNK	8200	4600	7.5	-	-	46	79	1300	470	ND	870	3200	ND	ND	-	0.49	1.1	-	0.59	0.34	-	-	-
MW-18	4/20/1999	BSK	7900	4600	7.4	3200	30.9	44	82	1500	510	<200	860	3904	<20	<10	-	0.4	1.1	-	0.6	0.34	-	-	-
MW-18	5/21/2000	BSK	6700	4000	7.5	3200	21.6	54	54	940	600	<150	630	3904	<15	<7.5	-	0.4	1.4	-	0.54	0.27	-	-	-
MW-18	12/19/2000	BSK	7200	3800	7.4	3000	18.6	52	54	800	550	<200	720	3660	<20	<10	-	0.4	1.3	-	0.44	0.26	-	-	-
MW-18	6/6/2001	BSK	6800	3700	7.4	2800	21.9	44	46	870	580	<200	780	3360	-	<10	-	0.4	1.2	-	0.58	0.24	-	-	-
MW-18	10/3/2001	UNK	6900	3600	7.4	-	-	39	57	950	530	ND	760	2800	ND	ND	-	0.4	1.1	-	0.6	0.18	-	-	-
MW-18	5/2/2002	BSK	7200	4100	7.8	2700	-	36	48	1100	380	<240	870	2700	<24	<12	-	0.4	1	-	0.4	0.19	-	-	-
MW-18	9/19/2002	TL	7100	4000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW-18	12/10/2002	BSK	6900	3800	7.8	2400	-	25	28	770	400	ND	770	-	-	ND	-	0.4	0.95	-	0.66	0.15	-	-	-
MW-18	1/13/2003	TL	7500	4000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW-18	3/22/2003	BSK	7000	3900	8.0	2600	-	26	28	1700	520	ND	820	-	-	ND	-	0.5	0.99	-	0.79	0.14	-	-	-
MW-18	3/23/2003	BSK	7000	3900	8.0	2600	-	26	28	1700	520	<120	820	3170	<0.9	<6	-	0.5	0.99	-	0.79	0.14	-	-	-
MW-18	9/30/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21	-	-	-	-	-	9.6	<0.4	-
MW-18	9/30/2003	TL	5700	3600	7.6	190	-	27	24	940	590	20	690	230	<1.8	-	-	0.51	0.89	<0.05	2.1	<0.03	-	-	<0.05
MW-18	10/25/2003	BSK	6600	3700	8.1	2500	-	31	28	970	460	ND	790	-	-	ND	-	0.4	0.86	-	0.91	0.13	-	-	-
MW-18	3/4/2004	TL	5200	2800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW-18	3/31/2004	BSK	5000	2700	8.1	2000	-	19	17	660	450	<2	540	2440	<0.9	<0.1	-	0.5	0.66	-	1	0.09	-	-	-
MW-18	4/1/2004	UNK	5000	2700	8.1	2000	-	19	17	660	450	ND	540	2000	ND	ND	-	0.5	0.66	-	1	0.09	-	-	-
MW-18	11/14/2004	BSK	5000	2800	8.0	2000	-	27	29	660	430	44	550	2440	<18	<2	-	0.5	0.66	-	0.27	0.12	-	-	-
MW-18	3/8/2005	TL	4700	2600	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6	-	-	-	0.12	<25	-	-
MW-18	4/6/2005	UNK	4200	2400	8.0	1800	-	29	27	670	260	ND	470	1800	ND	ND	-	0.56	0.48	-	0.22	0.17	-	-	-
MW-18	8/11/2005	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<6	-	-	-	-	-	105	31	-
MW-18	8/11/2005	TL	7100	5200	7.1	1800	-	89	71	1700	210	550	1100	2100	470	-	-	0.41	0.31	0.05	0.53	0.87	-	-	<0.025
MW-18	10/13/2005	UNK	5000	2800	8.0	1800	-	48	43	860	210	ND	610	1800	62	ND	-	0.6	0.43	-	0.14	0.39	-	-	-
MW-18	4/20/2006	UNK	5176	2740	7.5	1644	-	37	32	867	176	48	634	1644	ND	ND	-	0.34	0.36	-	0.13	0.41	-	-	-
MW-18	4/20/2006	TL	4600	2800	7.2	1100	-	39	35	930	220	54	600	-	<2	-	-	-	-	<0.01	6.5	0.4	-	-	<0.01
MW-18	9/26/2006	UNK	6715	3915	7.7	1451	-	47.5	38.4	1116	82.8	581	781	1451	276.2	ND	-	0.39	0.11	-	0.06	0.22	-	-	-
MW-18	9/26/2006	TL	5900	4100	7.4	1500	-	51	41	1400	120	480	710	-	260	-	<50	0.41	0.15	0.029	0.64	0.21	160	<100	<0.025
MW-18	3/28/2007	TL	4500	2800	7.4	1400	-	48	41	880	150	150	600	1700	-	-	ND	0.4	0.48	ND	0.18	0.47	23	ND	0.048
MW-18	9/24/2007	TL	4900	2800	7.2	1600	-	45	45	1100	150	100	600	2000	-	-	ND	0.44	0.35	0.031	0.61	0.45	-	-	ND
MW-18	4/5/2008	BCL	4010	2500	7.61	-	-	-	-	-	-	140	560	1464	<0.9	-	-	-	-	-	-	-	-	-	-
MW-18	9/4/2008	BCL	3500	2200	7.6	-	-	-	-	-	-	150	510	1220	2.3	-	-	-	0.16	-	-	-	-	-	-
MW-18	4/2/2009	BCL	4440	3500	7.7	1300	-	36	33	980	68	160	710	1600	ND	-	-	-	-	0.0023	3.8	0.42	-	-	0.0065
MW-18	4/2/2009	UNK	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.23	-	-	-	-	-	-
MW-18	10/2/2009	BSK	4300	2500	8.1	-	-	-	-	-	-	150	620	2074	<20	-	-	-	-	-	-	-	-	-	-
MW-18	10/20/2009	BCL	4320	2700	7.59	1300	-	38	38	920	98	150	640	1600	<2.2	-	8.5	0.35	0.3	<0.002	5.7	0.36	-	-	0.0065
MW-18	10/20/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	<0.4	-
MW-18	5/20/2010	BCL	3670	2400	7.72	1100	-	29	28	740	77	150	600	1300	<0.9	-	-	-	-	0.0021	4.3	0.24	-	-	0.0057
MW-18	9/15/2010	BCL	1990	1500	8.03	560	-	8	7	430	32	120	260	690	-	-	4.1	0.25	0.049	<0.002	1.1	0.072	-	-	<0.005
MW-18	9/15/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23.6	<0.4	-
MW-18	1/11/2011	SSC	1100	660	7.9	-	-	-	-	-	-	99	130	320	<2.2	-	-	-	-	-	-	-	-	-	-
MW-18	4/20/2011	BCL	1500	1000	8.07	360	-	8	5.6	370	18	140	200	440	11	-	-	-	-	0.0025	0.19	0.043	-	-	<0.005
MW-18	9/1/2011	BCL	5280	3600	7.92	940	-	43	22	1100	200	500	650	1100	470	-	4.1	0.29	0.14	0.024	0.17	0.025	-	-	0.0094
MW-18	9/1/2011	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18.1	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab [1]	EC [2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity [3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3 [3] (mg/L)	NO_3 [3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
SHALLOW (Spreckels)																									
MW-19	4/3/2009	UNK	8620	5300	7.5	-	-	-	-	-	-	1100	770	2400	ND	-	-	-	0.09	-	-	-	-	-	-
MW-19	10/1/2009	BSK	7600	3700	7.9	-	-	-	-	-	-	930	660	2806	<20	-	-	-	-	-	-	-	-	-	-
MW-19	10/19/2010	SSC	7100	4200	7.3	-	-	-	-	-	-	700	610	2700	2	-	-	-	-	-	-	-	-	-	-
MW-19	6/2/2011	SSC	6500	3800	7.4	-	-	-	-	-	-	480	650	1700	247.9	-	-	-	-	-	-	-	-	-	-
MW-19	10/3/2011	SSC	6700	4000	7.3	-	-	-	-	-	-	470	720	1800	287.8	-	-	-	-	-	-	-	-	-	-
MW-19	3/29/2012	BCL	5290	3700	7.77	-	-	-	-	-	-	110	260	1708	64	-	-	-	-	-	-	-	-	-	-
MW-19	10/4/2012	BCL	4780	3300	7.85	-	-	-	-	-	-	310	670	1342	230	-	-	-	-	-	-	-	-	-	-
MW-19	5/7/2013	BCL	5220	3300	7.9	-	-	-	-	-	-	460	750	1200	44	-	-	-	-	-	-	-	-	-	-
MW-19	10/24/2013	BCL	4840	3000	8.0	-	-	-	-	-	-	350	630	1300	<2.2	-	-	-	-	-	-	-	-	-	-
MW-19	5/15/2014	BCL	6010	3400	8.0	-	-	-	-	-	-	450	690	1500	2.1	-	-	-	-	-	-	-	-	-	-
MW-19	10/16/2014	BCL	6060	3400	7.8	-	-	-	-	-	-	520	730	1600	0.4	-	-	-	-	-	-	-	-	-	-
MW-20	5/21/1990	UNK	4000	2520	7.6	-	-	111	46	700	18	218	360	1545	-	-	-	-	-	-	1.445	2.059	-	-	-
MW-20	11/16/1990	UNK	-	2450	7.2	-	-	-	-	-	260	-	392	1106	-	-	-	0.43	0.379	-	3.12	1.95	-	-	-
MW-20	6/18/1991	UNK	4000	2340	7.2	-	-	-	-	-	30	-	408	1655	-	-	-	-	0.329	-	-	-	-	-	-
MW-20	10/22/1991	UNK	3200	2125	7.2	-	-	106	46	630	24	218	356	1410	-	0.06	-	0.37	0.237	-	2.33	1.74	-	-	-
MW-20	2/25/1992	UNK	3500	2040	7.6	-	-	115	44	585	22	210	333	1280	-	0.05	-	0.51	0.264	-	3.05	2.01	-	-	-
MW-20	10/23/1992	UNK	3100	1810	7.3	-	-	96	42	545	23	193	307	1210	-	0.06	-	0.25	0.19	-	2.5	1.6	-	-	-
MW-20	3/9/1993	UNK	3000	1700	7.8	-	-	91	41	518	20	205	305	1130	-	0.06	-	0.4	0.191	-	2.38	1.62	-	-	-
MW-20	9/23/1993	UNK	2440	2440	7.5	-	-	64	31	471	20	165	236	1010	-	0.06	-	0.36	0.23	-	1.43	1.24	-	-	-
MW-20	3/14/1994	UNK	2430	1510	7.4	-	-	71	33	447	22	155	226	1020	-	0.06	-	0.34	0.25	-	1.83	1.43	-	-	-
MW-20	10/3/1994	UNK	2420	1490	7.4	-	-	75	33	480	15.5	175	231	1030	-	0.07	-	0.35	0.232	-	-	1.43	-	-	-
MW-20	3/15/1995	UNK	2280	1380	7.6	-	-	70	30	406	12.2	165	215	818	-	0.06	-	0.38	0.2	-	-	1.29	-	-	-
MW-20	10/15/1995	UNK	2160	1320	7.8	-	-	66	29	389	11.6	170	203	871	-	0.06	-	0.38	0.193	-	-	1.29	-	-	-
MW-20	4/4/1996	UNK	2010	1150	8.48	-	-	56	26	376	10.7	158	176	818	-	0.06	-	0.42	0.183	-	-	1.14	-	-	-
MW-20	10/4/1996	UNK	2000	1220	7.6	-	-	58	24	362	10.9	157	170	803	-	0.06	-	0.45	0.172	-	-	1.06	-	-	-
MW-20	6/4/1997	UNK	1800	1300	7.4	-	-	67	28	430	11	170	200	630	-	-	-	0.46	0.18	-	-	1.1	-	-	-
MW-20	3/24/1998	UNK	2700	1590	7.4	-	-	74	34	468	21	170	243	1000	-	0.07	-	0.35	0.195	-	1.99	1.55	-	-	-
MW-20	8/25/1998	UNK	2100	1300	7.7	-	-	61	27	420	14	180	210	670	18.6	ND	-	0.41	0.18	-	ND	1.1	-	-	-
MW-20	4/21/1999	BSK	2000	1300	7.5	670	11.7	57	25	420	10	190	190	817	<4	<2	-	0.4	0.15	-	<0.05	1	-	-	-
MW-20	6/30/2000	UNK	2200	1300	7.5	600	-	54	25	380	10	220	170	600	ND	ND	-	0.4	0.12	-	ND	0.94	-	-	-
MW-20	12/19/2000	BSK	2200	1400	7.5	600	11.4	56	26	410	10	310	200	732	<5	<2.5	-	0.4	0.13	-	<0.05	0.89	-	-	-
MW-20	6/6/2001	BSK	2100	1400	7.3	580	10	64	28	380	11	300	220	708	-	<2.5	-	0.4	0.11	-	<0.05	1	-	-	-
MW-20	10/3/2001	UNK	2200	1400	7.4	-	-	58	27	420	10	280	200	560	ND	ND	-	0.3	0.11	-	ND	0.88	-	-	-
MW-20	5/2/2002	BSK	2400	1500	7.6	540	-	60	27	380	9	320	250	540	<6	<3	-	0.4	0.11	-	<0.05	1	-	-	-
MW-20	12/11/2002	BSK	2400	1500	8.0	600	-	56	26	410	10	300	260	-	-	ND	-	0.3	0.11	-	ND	0.93	-	-	-
MW-20	3/23/2003	BSK	2400	1500	7.9	620	-	58	28	400	9	290	280	-	-	ND	-	0.4	0.11	-	ND	1	-	-	-
MW-20	10/25/2003	BSK	2600	1600	8.2	660	-	66	31	430	11	-	-	-	-	ND	-	0.4	0.11	-	ND	1.1	-	-	-
MW-20	4/1/2004	UNK	2500	1600	8.0	680	-	73	36	480	10	290	320	680	ND	ND	-	0.4	0.13	-	ND	1.1	-	-	-
MW-20	11/15/2004	BSK	2400	1500	7.9	670	-	64	31	430	10	280	260	820	<2.7	<0.3	-	0.4	0.11	-	<0.05	1	-	-	-
MW-20	4/7/2005	UNK	2500	1500	8.0	690	-	67	32	460	11	310	300	690	ND	ND	-	0.4	0.14	-	ND	1.1	-	-	-
MW-20	10/14/2005	UNK	2600	1600	8.4	720	-	67	31	550	12	290	280	690	ND	ND	-	0.4	0.13	-	ND	1.2	-	-	-
MW-20	4/20/2006	DL	2610	1560	7.9	718	-	54	25	460	17	264	265	718	<0.1	<0.1	-	0.31	0.14	-	<0.01	0.98	-	-	-
MW-20	9/26/2006	UNK	2892	1703	7.9	667	-	59.8	27.8	533	17.6	353	336	667	ND	-	-	0.39	0.13	-	ND	1.15	-	-	-
MW-20	3/29/2007	TL	2600	1700	7.7	670	-	56	26	510	26	260	280	820	<20	<1	<10	0.41	0.17	<0.005	-	-	27	-	<0.005
MW-20	9/24/2007	TL	2700	1600	7.6	-	-	-	-	-	-	140	290	880	<50	-	-	-	-	-	-	-	-	-	-
MW-20	4/6/2008	BCL	2930	1900	7.78	-	-	-	-	-	-	280	340	1000	<0.4	-	-	-	-	-	-	-	-	-	-
MW-20	9/4/2008	BCL	2940	1800	7.8	-	-	-	-	-	-	300	340	1013	<0.4	-	-	-	0.15	-	-	-	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Cations				Anions					Trace Elements								
								Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
SHALLOW (Spreckels)																									
MW-21	5/6/2013	BCL	3570	2400	7.5	-	-	-	-	-	-	180	340	1400	<0.9	-	-	-	-	-	-	-	-	-	-
MW-21	10/24/2013	BCL	3820	2500	7.6	-	-	-	-	-	-	180	380	1400	<2.2	-	-	-	-	-	-	-	-	-	-
MW-21	5/16/2014	BCL	3910	2400	6.8	-	-	-	-	-	-	200	360	1100	<0.9	-	-	-	-	-	-	-	-	-	-
MW-21	10/17/2014	BCL	3840	2000	7.3	-	-	-	-	-	-	200	340	1400	ND	-	-	-	-	-	-	-	-	-	-
MW-23	4/12/1990	UNK	8400	4460	7.5	-	-	78	69	900	559	132	777	3756	-	-	-	-	-	0.195	0.566	-	-	-
MW-23	11/19/1990	UNK	-	4060	7.2	-	-	-	-	-	580	-	783	2616	-	-	-	0.25	2.94	-	0.573	0.717	-	-	-
MW-23	6/19/1991	UNK	8000	4200	7.2	-	-	-	-	-	595	-	776	3838	-	-	-	-	2.69	-	-	-	-	-	-
MW-23	10/23/1991	UNK	7500	3930	7.1	-	-	101	78	920	565	122	748	3480	-	-	-	0.23	2.42	-	6.45	0.635	-	-	-
MW-23	3/12/1992	UNK	7400	3900	7.4	-	-	98	70	840	615	102	644	3410	-	-	-	0.43	3.16	-	6.81	0.592	-	-	-
MW-23	10/26/1992	UNK	6500	3380	7.2	-	-	88	64	820	470	125	570	2940	-	-	-	0.26	2.1	-	5.11	0.561	-	-	-
MW-23	3/5/1993	UNK	6500	3340	7.3	-	-	102	75	825	487	135	585	2970	-	0.05	-	0.33	1.24	-	6.6	0.674	-	-	-
MW-23	9/24/1993	UNK	6000	3000	7.4	-	-	108	78	781	385	120	580	2730	-	0.06	-	0.27	1.76	-	6.89	0.71	-	-	-
MW-23	4/11/1994	UNK	6000	3210	7.0	-	-	81	62	780	489	80	542	2890	-	0.08	-	0.32	1.91	-	5.2	0.583	-	-	-
MW-23	10/4/1994	UNK	6280	3500	7.0	-	-	87	67	755	506	80	570	2990	-	-	-	0.29	2.02	-	0.91	0.57	-	-	-
MW-23	3/30/1995	UNK	5230	2820	7.0	-	-	61	51	705	390	42	470	2590	-	-	-	0.3	1.29	-	0.15	0.42	-	-	-
MW-23	3/24/1998	UNK	3900	2400	7.5	-	-	48	32	630	380	120	410	1700	-	-	-	0.37	0.81	-	-	0.31	-	-	-
MW-23	4/22/1999	BSK	4900	2700	7.3	1900	16	53	35	610	450	140	400	2318	<5	<5	-	0.38	0.85	-	0.15	0.42	-	-	-
MW-23	5/21/2000	BSK	4100	2500	7.2	1700	16.8	30	24	510	390	140	360	2074	<10	<5	-	0.4	0.49	-	0.07	0.42	-	-	-
MW-23	12/19/2000	BSK	4900	2500	7.4	1700	13.5	51	30	490	360	200	400	2074	<10	<5	-	0.4	0.6	-	0.21	0.43	-	-	-
MW-23	6/4/2001	BSK	4400	2400	7.4	1600	18.6	30	22	550	380	180	390	1952	<8	<4	-	0.4	0.46	-	0.2	0.36	-	-	-
MW-23	6/10/2001	UNK	4400	2400	7.4	1600	-	30	22	550	380	180	390	1600	ND	ND	-	0.4	0.46	-	0.2	0.36	-	-	-
MW-23	10/3/2001	UNK	4200	2200	7.2	1500	-	44	28	540	350	210	360	1500	ND	ND	-	0.4	0.4	-	0.14	0.38	-	-	-
MW-23	5/2/2002	BSK	3800	2400	7.7	1200	-	41	23	450	230	240	340	1200	<10	<5	-	0.4	0.28	-	0.07	0.42	-	-	-
MW-23	12/11/2002	BSK	3700	2000	8.1	-	-	40	22	420	230	220	310	-	-	ND	-	0.3	0.21	-	0.1	0.63	-	-	-
MW-23	3/22/2003	BSK	1300	1900	7.9	1200	-	17	15	460	210	94	-	-	-	ND	-	0.5	0.23	-	0.14	0.21	-	-	-
MW-23	10/24/2003	BSK	3300	1800	7.8	1100	-	36	21	440	230	170	280	-	-	ND	-	0.4	0.24	-	0.09	0.4	-	-	-
MW-23	3/31/2004	BSK	3300	1900	7.8	1200	-	18	16	490	230	150	300	1460	<0.9	<0.1	-	0.5	0.21	-	0.08	0.19	-	-	-
MW-23	11/14/2004	BSK	3000	1700	8.0	1200	-	16	14	440	210	83	240	1460	<9	<1	-	0.4	0.2	-	0.12	0.17	-	-	-
MW-23	4/7/2005	UNK	3400	1800	7.7	1400	-	17	14	470	260	63	260	1400	ND	ND	-	0.4	0.25	-	0.1	0.19	-	-	-
MW-23	10/14/2005	UNK	3400	1800	8.2	1400	-	18	17	490	250	82	230	1400	ND	ND	-	0.5	ND	-	0.1	0.22	-	-	-
MW-23	4/19/2006	DL	3804	1963	7.7	1575	-	16	15	720	559	34	246	1575	<0.1	<0.1	-	0.29	0.35	-	0.15	0.21	-	-	-
MW-23	9/25/2006	UNK	3502	1855	7.5	1100	-	17.5	13.4	423	270	59	264	1100	ND	ND	-	0.36	0.26	-	0.14	0.29	-	-	-
MW-23	4/2/2009	UNK	3800	2200	7.7	-	-	-	-	-	-	100	290	1500	ND	-	-	-	0.39	-	-	-	-	-	-
MW-23	10/1/2009	BSK	3200	1700	8.0	-	-	-	-	-	-	88	240	1586	<10	-	-	-	-	-	-	-	-	-	-
MW-23	10/19/2010	SSC	3300	1800	7.3	-	-	-	-	-	-	99	250	1600	<2	-	-	-	-	-	-	-	-	-	-
MW-23	6/2/2011	SSC	4700	2400	7.3	-	-	-	-	-	-	180	360	1800	<2.2	-	-	-	-	-	-	-	-	-	-
MW-23	10/3/2011	SSC	5200	2700	7.3	-	-	-	-	-	-	230	420	1900	<2.2	-	-	-	-	-	-	-	-	-	-
MW-23	3/30/2012	BCL	5920	3300	7.85	-	-	-	-	-	-	370	510	2318	<2.2	-	-	-	-	-	-	-	-	-	-
MW-23	4/3/2012	BCL	-	-	-	-	-	-	-	-	-	-	520	2440	-	-	-	-	-	-	-	-	-	-	-
MW-23	10/4/2012	BCL	5680	3400	7.48	-	-	-	-	-	-	400	520	2440	<2.2	-	-	-	-	-	-	-	-	-	-
MW-23	5/6/2013	BCL	5690	3400	7.5	-	-	-	-	-	-	360	560	2000	<2.2	-	-	-	-	-	-	-	-	-	-
MW-23	10/24/2013	BCL	5290	3000	7.5	-	-	-	-	-	-	290	500	1800	<2.2	-	-	-	-	-	-	-	-	-	-
MW-23	5/16/2014	BCL	4810	2600	8.2	-	-	-	-	-	-	220	440	1700	<2.2	-	-	-	-	-	-	-	-	-	-
MW-23	10/17/2014	BCL	4420	2200	7.3	-	-	-	-	-	-	190	360	1500	ND	-	-	-	-	-	-	-	-	-	-
MW-24	4/12/1990	UNK	1670	1110	7.1	-	-	121	43	157	11	236	276	259	-	-	-	-	-	8.731	1.888	-	-	-
MW-24	11/19/1990	UNK	-	1180	7.0	-	-	-	-	-	17.2	-	341	291	-	-	-	0.14	-	10.9	2.14	-	-	-
MW-24	6/19/1991	UNK	2300	1530	7.0	-	-	-	-	-	15.6	-	367	417	-	-	-	-	-	-	-	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
SHALLOW (Spreckels)																									
MW-25	3/5/1993	UNK	2800	1620	7.9	-	-	26	17.2	588	2.1	164	260	1100	-	0.32	-	0.61	-	-	0.585	0.611	-	-	-
MW-25	9/24/1993	UNK	2800	1550	8.0	-	-	20	15	578	2	155	260	1030	-	0.2	-	0.65	-	-	0.46	0.47	-	-	-
MW-25	4/13/1994	UNK	2640	1640	7.8	-	-	22	12.8	651	2.1	170	247	1050	-	0.14	-	0.58	-	-	0.431	0.392	-	-	-
MW-25	10/4/1994	UNK	2630	1610	7.8	-	-	18.8	11.5	600	2	180	260	998	-	0.1	-	0.59	-	-	0.45	0.41	-	-	-
MW-25	3/21/1995	UNK	2600	1600	7.9	-	-	18.7	10.6	600	2	186	270	969	-	0.13	-	0.64	-	-	0.07	0.387	-	-	-
MW-25	10/18/1995	UNK	2520	1950	7.9	-	-	17	9.2	558	1.7	225	280	863	-	0.1	-	0.55	-	-	0.061	0.37	-	-	-
MW-25	4/3/1996	UNK	2480	1640	8.0	-	-	16	9.1	552	1.7	215	282	843	-	0.1	-	0.52	-	-	0.169	0.357	-	-	-
MW-25	10/8/1996	UNK	2500	1450	8.8	-	-	17.1	10.7	576	2	212	308	783	-	0.1	-	0.53	-	-	0.059	0.387	-	-	-
MW-25	3/25/1997	UNK	2500	1700	7.7	-	-	25	15	650	3400	270	350	670	-	-	-	0.57	0.1	-	-	0.52	-	-	-
MW-25	6/7/1997	UNK	-	8100	7.9	-	-	13.4	15.6	1440	2040	9	1320	7270	19.5	0.12	-	0.34	1.74	-	1.72	0.02	-	-	-
MW-25	8/27/1998	UNK	2900	1700	7.9	-	-	25	16	660	5700	270	350	710	ND	ND	-	0.56	0.1	-	ND	0.55	-	-	-
MW-25	4/21/1999	BSK	2800	1800	7.9	700	22.6	29	16	610	3	280	350	854	<6	<3	-	0.5	0.09	-	<0.05	0.6	-	-	-
MW-25	11/14/1999	UNK	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW-25	5/21/2000	BSK	2300	1600	7.6	760	21.7	24	13	530	2	160	300	927	<5	<2.5	-	0.5	0.08	-	0.14	0.55	-	-	-
MW-25	12/17/2000	UNK	2600	1600	7.6	750	-	22	13	540	300	150	320	750	ND	ND	-	0.5	0.07	-	0.05	0.44	-	-	-
MW-25	12/19/2000	BSK	2600	1600	7.6	750	22.6	22	13	540	3	150	320	915	<6	<3	-	0.5	0.07	-	0.05	0.44	-	-	-
MW-25	6/6/2001	BSK	2400	1500	7.7	800	21.5	23	13	520	3	160	330	976	-	<3	-	0.5	0.07	-	0.1	0.47	-	-	-
MW-25	6/15/2001	UNK	2400	1500	7.7	800	-	23	13	520	300	160	330	800	ND	ND	-	0.5	0.07	-	0.1	0.47	-	-	-
MW-25	10/3/2001	UNK	2500	1600	7.5	710	-	20	13	530	ND	150	300	710	ND	ND	-	0.5	0.07	-	0.12	0.4	-	-	-
MW-25	5/2/2002	BSK	2500	1400	7.1	1000	-	20	12	530	2	200	310	1000	<8	<4	-	0.6	0.07	-	0.11	0.4	-	-	-
MW-25	12/10/2002	BSK	2400	1400	7.8	640	-	18	11	480	3	190	290	-	-	ND	-	0.7	0.06	-	0.16	0.34	-	-	-
MW-25	3/23/2003	BSK	2500	1500	8.0	630	-	16	9.6	470	ND	210	310	-	-	ND	-	0.8	0.06	-	0.18	0.36	-	-	-
MW-25	10/24/2003	BSK	2600	1500	8.4	710	-	18	12	500	3	190	-	-	-	ND	-	0.7	0.06	-	0.14	0.38	-	-	-
MW-25	4/1/2004	UNK	2600	1600	8.2	710	-	23	15	600	3	430	650	710	ND	ND	-	0.8	0.09	-	0.06	0.55	-	-	-
MW-25	11/14/2004	BSK	2600	1600	8.1	820	-	39	31	520	2	180	340	1000	<9	<1	-	0.6	0.1	-	<0.05	1	-	-	-
MW-25	4/7/2005	UNK	2800	1600	8.0	810	-	55	38	510	2	220	360	810	ND	ND	-	0.6	0.13	-	ND	1.3	-	-	-
MW-25	10/13/2005	UNK	2900	1800	8.1	740	-	64	38	570	3	320	370	740	ND	ND	-	0.7	0.15	-	ND	1.4	-	-	-
MW-25	4/19/2006	DL	3528	2078	7.8	777	-	67	37	584	9.3	461	382	777	<0.1	<0.1	-	0.72	0.17	-	<0.01	1.4	-	-	-
MW-25	9/25/2006	UNK	3658	2313	7.8	255	-	70.4	39	679	6.6	572	461	255	ND	ND	-	0.82	0.18	-	0.03	1.52	-	-	-
MW-25	3/29/2007	TL	3700	2500	7.6	910	-	72	41	750	14	460	420	1100	<20	<1	<10	0.98	0.21	0.0065	-	-	74	-	<0.005
MW-25	9/24/2007	TL	3600	2100	7.5	-	-	-	-	-	-	410	390	1100	<50	-	-	-	-	-	-	-	-	-	-
MW-25	4/6/2008	BCL	3520	2300	7.84	-	-	-	-	-	-	400	450	1159	<0.9	-	-	-	-	-	-	-	-	-	-
MW-25	9/4/2008	BCL	3470	2300	7.8	-	-	-	-	-	-	320	430	1208	<0.4	-	-	-	0.13	-	-	-	-	-	-
MW-25	4/3/2009	UNK	3470	2400	7.6	-	-	-	-	-	-	390	460	910	ND	-	-	-	0.16	-	-	-	-	-	-
MW-25	10/2/2009	BSK	3400	2100	8.1	-	-	-	-	-	-	350	440	1171	<20	-	-	-	-	-	-	-	-	-	-
MW-25	10/19/2010	SSC	3600	2200	7.4	-	-	-	-	-	-	350	450	1200	<2	-	-	-	-	-	-	-	-	-	-
MW-25	6/2/2011	SSC	3300	2200	7.4	-	-	-	-	-	-	250	430	1000	<2.2	-	-	-	-	-	-	-	-	-	-
MW-25	10/3/2011	SSC	3400	2100	7.4	-	-	-	-	-	-	180	410	1100	<2.2	-	-	-	-	-	-	-	-	-	-
MW-25	3/30/2012	BCL	3320	2100	7.89	-	-	-	-	-	-	83	370	1464	<0.9	-	-	-	-	-	-	-	-	-	-
MW-25	10/4/2012	BCL	3020	2100	7.65	-	-	-	-	-	-	67	370	1464	<0.9	-	-	-	-	-	-	-	-	-	-
MW-25	5/7/2013	BCL	3160	2100	7.8	-	-	-	-	-	-	64	340	1200	<0.9	-	-	-	-	-	-	-	-	-	-
MW-25	10/24/2013	BCL	3160	2100	7.8	-	-	-	-	-	-	57	380	1200	<0.9	-	-	-	-	-	-	-	-	-	-
MW-25	5/15/2014	BCL	3590	2200	7.8	-	-	-	-	-	-	96	410	1100	<0.4	-	-	-	-	-	-	-	-	-	-
MW-25	10/17/2014	BCL	3350	2000	7.5	-	-	-	-	-	-	110	430	1100	1.9	-	-	-	-	-	-	-	-	-	-
MW-26	4/12/1990	UNK	14000	8340	7.8	-	-	6.2	16	1280	2150	64	1145	7553	-	-	-	-	-	-	1.79	0.027	-	-	-
MW-26	11/19/1990	UNK	-	7700	7.8	-	-	-	-	-	1780	-	1102	5694	-	-	-	-	1.95	-	2.73	0.062	-	-	-
MW-26	6/19/1991	UNK	15300	8640	7.6	-	-	-	-	-	1890	-	1241	8693	-	-	-	-	2.15	-	-	-	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
SHALLOW (Spreckels)																									
MW-27	4/13/1994	UNK	8530	4150	7.2	-	-	47	40	798	1260	6	683	4180	-	0.14	-	0.3	2.05	-	4.6	0.121	-	-	-
MW-27	10/8/1996	UNK	13800	6900	8.7	-	-	48	40	1390	2120	14.5	1360	7090	-	0.12	-	-	4.25	-	1.35	0.054	-	-	-
MW-27	6/7/1997	UNK	12900	7020	7.8	-	-	38	28	1190	1860	133	1090	6240	-	0.11	-	0.36	3.32	-	1.12	0.057	-	-	-
MW-27	3/30/1998	UNK	9800	6000	7.6	-	-	32	23	1200	1700	240	990	4100	-	-	-	0.29	2.2	-	1.2	0.08	-	-	-
MW-27	8/29/1998	UNK	11000	5700	7.6	-	-	38	30	1000	1600	13	57	4200	ND	ND	-	0.35	2.2	-	1.5	0.14	-	-	-
MW-27	4/21/1999	BSK	9500	5200	7.9	3700	33.7	29	23	1000	1600	210	850	4514	<20	<10	-	0.3	1.8	-	1.1	0.12	-	-	-
MW-27	5/21/2000	BSK	7500	4500	7.4	3500	21.8	44	34	790	1000	220	750	4270	<20	<10	-	0.3	1.4	-	1.3	0.16	-	-	-
MW-27	12/17/2000	BSK	7600	4200	7.5	3200	21.7	42	34	780	940	<200	730	3904	<20	<10	-	0.3	1.4	-	0.8	0.19	-	-	-
MW-27	6/6/2001	BSK	7100	4100	7.4	3000	20.8	45	34	760	930	<200	720	3660	-	<10	-	0.3	1.3	-	1.2	0.21	-	-	-
MW-27	6/15/2001	UNK	7100	4100	7.4	3000	-	45	34	760	930	ND	720	3000	1.3	ND	-	0.3	1.3	-	1.2	0.21	-	-	-
MW-27	10/3/2001	UNK	7100	4000	7.5	2700	-	37	31	720	890	ND	640	2700	ND	ND	-	0.3	1.1	-	0.69	0.15	-	-	-
MW-27	5/2/2002	BSK	7400	4700	7.8	3100	-	30	27	630	700	<240	680	3100	<24	<12	-	0.3	1.1	-	0.72	0.11	-	-	-
MW-27	12/10/2002	UNK	7300	4100	7.8	2700	-	25	21	590	710	ND	630	2700	ND	ND	-	0.3	1.1	-	0.97	0.1	-	-	-
MW-27	3/22/2003	BSK	7500	4200	7.9	3000	-	32	29	700	860	ND	680	-	-	ND	-	0.3	1.2	-	0.96	0.12	-	-	-
MW-27	10/24/2003	BSK	7300	4000	7.9	2900	-	34	30	760	900	ND	640	-	-	ND	-	0.3	1.2	-	1	0.1	-	-	-
MW-27	3/31/2004	BSK	7000	3900	8.0	2900	-	34	28	700	880	130	650	3540	<0.9	<0.1	-	0.3	1.1	-	0.86	0.07	-	-	-
MW-27	11/14/2004	BSK	6500	3600	8.1	2500	-	34	26	670	840	340	510	3050	<22	<2.5	-	0.4	0.78	-	0.71	0.08	-	-	-
MW-27	4/6/2005	UNK	5600	3100	8.0	1900	-	36	26	580	700	490	480	1900	ND	ND	-	0.4	0.39	-	0.46	0.07	-	-	-
MW-27	10/13/2005	UNK	5500	3100	8.0	1700	-	60	31	650	680	500	470	1700	ND	ND	-	0.5	0.19	-	0.47	0.26	-	-	-
MW-27	4/20/2006	DL	6004	3443	7.9	2111	-	54	40	1004	1326	289	570	2111	<0.1	<0.1	-	0.28	0.27	-	0.59	0.08	-	-	-
MW-27	9/25/2006	UNK	7980	4040	7.5	2219	-	70.6	38.2	743	612	333	788	2219	8	ND	-	0.32	0.36	-	0.31	0.39	-	12	-
MW-27	3/29/2007	TL	7000	4000	7.6	2300	-	50	28	810	760	220	690	2800	<50	<2.5	41	0.36	0.43	0.023	-	-	8.1	-	0.14
MW-27	9/24/2007	TL	6200	3400	7.5	-	-	-	-	-	-	250	600	2400	<100	-	-	-	-	-	-	-	-	-	-
MW-27	9/3/2008	BCL	6290	3700	7.7	-	-	-	-	-	-	420	800	2318	6.6	-	-	-	0.3	-	-	-	-	-	-
MW-27	4/3/2009	UNK	5990	3700	7.7	-	-	-	-	-	-	410	720	1900	ND	-	-	-	0.12	-	-	-	-	-	-
MW-27	10/2/2009	BSK	6000	2900	8.2	-	-	-	-	-	-	370	660	2318	<20	-	-	-	-	-	-	-	-	-	-
MW-27	1/11/2011	SSC	3200	1800	7.3	-	-	-	-	-	-	320	480	690	24.3	-	-	-	-	-	-	-	-	-	-
MW-27	5/4/2011	SSC	670	340	7.5	-	-	-	-	-	-	68	54	140	<2.2	-	-	-	-	-	-	-	-	-	-
MW-27	9/12/2011	SSC	770	430	7.8	-	-	-	-	-	-	86	75	160	<2.2	-	-	-	-	-	-	-	-	-	-
MW-27	3/30/2012	BCL	713	410	7.97	-	-	-	-	-	-	77	91	146	2.2	-	-	-	-	-	-	-	-	-	-
MW-27	10/4/2012	BCL	770	460	7.76	-	-	-	-	-	-	78	110	171	2.2	-	-	-	-	-	-	-	-	-	-
MW-27	5/6/2013	BCL	882	550	7.9	-	-	-	-	-	-	91	110	200	<0.4	-	-	-	-	-	-	-	-	-	-
MW-27	10/23/2013	BCL	1300	700	8.1	-	-	-	-	-	-	120	160	270	<0.4	-	-	-	-	-	-	-	-	-	-
MW-27	5/16/2014	BCL	1370	780	8.1	-	-	-	-	-	-	140	170	280	<0.4	-	-	-	-	-	-	-	-	-	-
MW-27	10/15/2014	BCL	1410	760	7.9	-	-	-	-	-	-	120	170	300	ND	-	-	-	-	-	-	-	-	-	-
MW-28	10/10/1991	BCL	2900	1650	7.6	-	6.9	152	62	397	7	219	270	-	-	-	-	-	-	-	-	-	-	-	-
MW-28	10/26/1992	UNK	1920	1270	7.5	-	-	145	49	212	9.1	287	175	600	-	0.05	-	0.29	0.112	-	2.18	2.14	-	-	-
MW-28	3/5/1993	UNK	2400	1330	7.4	-	-	145	48	275	9.3	275	216	679	-	0.06	-	0.39	0.106	-	2.22	1.98	-	-	-
MW-28	9/24/1993	UNK	1850	1140	7.4	-	-	119	40	235	8.3	315	177	500	-	0.05	-	0.31	0.107	-	1.67	1.65	-	-	-
MW-28	3/30/1994	UNK	1720	1160	7.5	-	-	100	36	242	8.6	345	148	408	-	-	-	0.29	-	-	-	1.14	-	-	-
MW-28	4/13/1994	UNK	1870	1230	7.4	-	-	128	35	241	8.4	325	171	487	-	0.05	-	0.31	-	-	1.53	1.4	-	-	-
MW-28	9/23/1994	UNK	1750	1140	7.4	-	-	114	39	203	8.3	310	152	428	-	0.06	-	0.28	0.1	-	1.61	1.48	-	-	-
MW-28	3/30/1995	UNK	1720	1160	7.5	-	-	100	36	242	8.6	345	148	408	-	-	-	0.29	-	-	-	1.14	-	-	-
MW-28	10/18/1995	UNK	1700	1180	7.5	-	-	110	34	210	6.5	335	162	423	-	0.05	-	0.32	-	-	-	1.21	-	-	-
MW-28	4/8/1996	UNK	1750	1110	8.4	-	-	114	37	218	7.2	392	160	404	-	0.1	-	0.35	-	-	-	1.19	-	-	-
MW-28	10/9/1996	UNK	1800	1180	8.19	-	-	109	37	250	7.7	352	169	448	-	0.05	-	0.33	-	-	-	1.21	-	-	-
MW-28	6/9/1997	UNK	1840	1190	7.4	-	-	109	39	254	7.9	364	172	455	-	0.05	-	0.38	-	-	-	1.53	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
SHALLOW (Spreckels)																									
MW-29	4/22/1999	BSK	1800	1300	7.1	470	3.2	170	45	180	6	290	210	573	<4	<2	-	0.2	0.09	-	<0.05	1.7	-	-	-
MW-29	5/20/2000	BSK	1700	1200	6.8	320	2.2	170	51	130	7	340	180	390	<4	<2	-	0.1	0.06	-	2.5	2.2	-	-	-
MW-29	12/18/2000	BSK	1800	1100	7.4	290	2.2	140	53	120	7	360	170	354	<4	<2	-	0.1	0.07	-	0.46	2.3	-	-	-
MW-29	6/5/2001	BSK	1600	1200	6.7	270	2.1	150	60	120	7	390	170	329	<4	<2	-	0.1	0.07	-	1	2.5	-	-	-
MW-29	10/4/2001	UNK	1600	1200	6.7	210	-	160	61	100	6	440	140	210	ND	ND	-	0.1	0.07	-	0.26	2.8	-	-	-
MW-29	5/2/2002	BSK	1600	1200	6.6	200	-	160	62	88	7	470	140	200	<4	<2	-	<0.1	0.06	-	0.69	2.8	-	-	-
MW-29	12/13/2002	BSK	1500	1000	6.9	220	-	130	52	85	6	380	150	-	-	ND	-	0.1	ND	-	1.3	2.3	-	-	-
MW-29	3/23/2003	BSK	1500	1100	6.8	210	-	140	51	83	6	400	-	-	-	ND	-	0.1	0.05	-	3	-	-	-	-
MW-29	10/24/2003	BSK	1500	1100	7.5	180	-	150	62	87	-	510	-	-	-	ND	-	ND	0.05	-	-	3	-	-	-
MW-29	4/1/2004	UNK	1500	1100	7.7	310	-	160	52	110	8	300	170	310	ND	ND	-	0.1	0.05	-	3.1	2.4	-	-	-
MW-29	11/15/2004	BSK	1700	1200	7.6	410	-	170	53	150	7	300	190	500	<2.7	<0.3	-	0.2	0.06	-	0.13	2.2	-	-	-
MW-29	4/7/2005	UNK	1800	1200	7.7	370	-	170	46	160	7	380	180	370	ND	ND	-	0.2	0.06	-	ND	2	-	-	-
MW-29	10/14/2005	UNK	1900	1300	8.2	370	-	180	47	180	8	420	170	370	ND	ND	-	0.2	0.06	-	ND	2	-	-	-
MW-29	4/19/2006	DL	1892	1360	7.4	470	-	147	40	228	11.8	391	181	470	<0.1	<0.1	-	0.19	0.06	-	2.31	1.87	-	-	-
MW-29	3/29/2007	TL	2200	1500	7.2	520	-	160	46	310	16	410	210	630	<6.6	<0.5	<10	0.25	0.084	0.009	-	-	<5	-	0.21
MW-29	9/25/2007	TL	1700	1300	7.1	-	-	-	-	-	-	400	71	420	<10	-	-	-	-	-	-	-	-	-	-
MW-29	4/6/2008	BCL	2180	1500	7.39	-	-	-	-	-	-	370	230	647	<0.4	-	-	-	-	-	-	-	-	-	-
MW-29	9/4/2008	BCL	1800	1300	7.2	-	-	-	-	-	-	470	180	366	<0.4	-	-	-	0.052	-	-	-	-	-	-
MW-29	4/3/2009	UNK	1930	1400	7.3	-	-	-	-	-	-	430	210	400	ND	-	-	-	0.06	-	-	-	-	-	-
MW-29	10/5/2009	BSK	1800	1200	7.7	-	-	-	-	-	-	470	160	366	<10	-	-	-	-	-	-	-	-	-	-
MW-29	10/6/2010	SSC	2000	1200	7.0	-	-	-	-	-	-	250	190	573	<2	-	-	-	-	-	-	-	-	-	-
MW-29	5/19/2011	SSC	2000	1200	7.0	-	-	-	-	-	-	270	190	510	<2.2	-	-	-	-	-	-	-	-	-	-
MW-29	9/21/2011	SSC	1900	1100	6.9	-	-	-	-	-	-	270	180	450	<2.2	-	-	-	-	-	-	-	-	-	-
MW-29	3/30/2012	BCL	1870	1200	7.53	-	-	-	-	-	-	280	180	525	<0.4	-	-	-	-	-	-	-	-	-	-
MW-29	10/4/2012	BCL	1790	1300	7.38	-	-	-	-	-	-	410	180	476	<0.9	-	-	-	-	-	-	-	-	-	-
MW-29	5/7/2013	BCL	1780	1300	7.5	-	-	-	-	-	-	350	170	380	<0.4	-	-	-	-	-	-	-	-	-	-
MW-29	10/24/2013	BCL	1750	1300	7.4	-	-	-	-	-	-	420	170	300	<0.9	-	-	-	-	-	-	-	-	-	-
MW-29	5/16/2014	BCL	1820	1300	8.1	-	-	-	-	-	-	450	180	310	<0.9	-	-	-	-	-	-	-	-	-	-
MW-29	10/17/2014	BCL	1820	1200	7.3	-	-	-	-	-	-	430	170	300	ND	-	-	-	-	-	-	-	-	-	-
MW-30	10/11/1991	BCL	240	160	7.3	-	0.8	18	7.7	15	2.3	34	7.1	-	-	-	-	-	-	-	-	-	-	-	-
MW-30	10/26/1992	UNK	250	160	7.3	-	-	18.7	7.2	13.1	2.3	37	6.8	71.3	-	0.1	-	-	-	-	0.123	0.095	-	-	-
MW-30	3/5/1993	UNK	270	175	7.1	-	-	21	8.4	13.9	2.5	51	6.1	71.3	-	0.07	-	-	-	-	0.052	0.02	-	-	-
MW-30	9/24/1993	UNK	290	160	7.2	-	-	24	10	15	2.6	62	6.4	71.3	-	0.07	-	-	-	-	0.167	0.046	-	-	-
MW-30	3/30/1994	UNK	290	140	7.2	-	-	22	10	15.3	2.4	63	6.1	67	-	0.06	-	-	-	-	0.241	0.037	-	-	-
MW-30	4/13/1994	UNK	310	215	7.1	-	-	27	10.6	17	2.7	80	5.4	67	-	0.06	-	-	-	-	0.284	0.044	-	-	-
MW-30	9/23/1994	UNK	288	180	7.2	-	-	21	9.9	17	2.6	61	6.4	70.4	-	0.06	-	-	-	-	0.45	0.045	-	-	-
MW-30	3/30/1995	UNK	288	215	7.2	-	-	21	10.5	18.6	2.5	65	8.9	73.9	-	0.05	-	-	-	-	0.11	0.062	-	-	-
MW-30	10/18/1995	UNK	288	210	7.2	-	-	21	9.6	16.8	2.2	65	8	72.2	-	0.07	-	-	-	-	0.35	0.059	-	-	-
MW-30	4/8/1996	UNK	314	190	8.0	-	-	24	10.8	18.8	2.4	74	11.1	70.4	-	0.05	-	-	-	-	0.164	0.082	-	-	-
MW-30	10/9/1996	UNK	362	235	8.0	-	-	29	14.1	19.1	2.8	74.3	19.4	79.1	-	0.06	-	-	-	-	0.07	0.08	-	-	-
MW-30	6/9/1997	UNK	469	308	7.0	-	-	43	17.8	19.6	3	142	13.5	68.7	-	0.06	-	-	-	-	0.182	0.116	-	-	-
MW-30	3/26/1998	UNK	440	310	7.0	-	-	48	18	26	3.6	140	21	56	-	-	-	-	0.05	-	-	0.16	-	-	-
MW-30	8/29/1998	UNK	900	640	7.1	-	-	110	44	27	6.5	380	14	52	6.2	ND	-	0.24	0.13	-	ND	0.36	-	-	-
MW-30	4/22/1999	BSK	500	370	6.4	60	0.5	46	18	17	3	170	13	73	<2	<1	-	<0.1	<0.05	-	<0.05	0.05	-	-	-
MW-30	5/20/2000	BSK	360	230	6.5	60	-	35	14	16	<2	96	10	73	<1	<0.5	-	<0.1	<0.05	-	0.08	0.06	-	-	-
MW-30	12/18/2000	BSK	400	240	6.4	60	0.6	32	14	16	2	110	9	73	<0.8	<0.4	-	<0.1	<0.05	-	0.08	0.06	-	-	-
MW-30	6/5/2001	BSK	340	250	6.2	56	0.6	32	13	15	3	100	8	68	<0.6	<0.3	-	<0.1	<0.05	-	0.09	0.06	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
SHALLOW (Spreckels)																									
MW-31	12/13/2002	UNK	880	650	6.7	76	-	72	25	55	4	270	130	76	ND	ND	-	ND	ND	-	0.38	0.53	-	-	-
MW-31	3/22/2003	BSK	880	610	6.4	80	-	75	26	56	4	310	52	-	-	0.1	-	ND	ND	-	0.48	0.56	-	-	-
MW-31	10/25/2003	BSK	910	620	7.6	84	-	72	26	58	5	290	47	-	-	ND	-	ND	ND	-	0.34	0.55	-	-	-
MW-31	4/1/2004	UNK	890	630	7.3	90	-	85	30	66	6	300	49	90	ND	0.2	-	ND	ND	-	1.1	0.65	-	-	-
MW-31	11/15/2004	BSK	-	630	7.2	84	-	79	30	65	5	310	47	100	<1.8	<0.2	-	<0.1	<0.05	-	0.48	0.65	-	-	-
MW-31	4/7/2005	UNK	820	550	7.5	84	-	72	26	59	5	280	44	84	ND	ND	-	ND	ND	-	ND	0.59	-	-	-
MW-31	10/14/2005	UNK	940	640	7.8	79	-	81	30	62	7	320	48	79	ND	ND	-	ND	ND	-	0.98	0.68	-	-	-
MW-31	4/19/2006	DL	753	525	7.3	84	-	67	24	55	7.2	249	43	84	<0.1	<0.1	-	0.04	0.02	-	0.65	0.54	-	-	-
MW-31	3/29/2007	TL	710	530	7.3	86	-	68	22	51	7.4	220	38	100	<4	<0.2	<10	0.05	0.021	<0.005	-	-	<5	-	0.089
MW-31	9/25/2007	TL	790	580	6.8	-	-	-	-	-	-	260	41	100	<6	-	-	-	-	-	-	-	-	-	-
MW-31	4/6/2008	BCL	792	560	7.47	-	-	-	-	-	-	250	40	120	<0.4	-	-	-	-	-	-	-	-	-	-
MW-31	9/4/2008	BCL	828	590	7.2	-	-	-	-	-	-	260	42	106	<0.4	-	-	-	0.022	-	-	-	-	-	-
MW-31	4/3/2009	UNK	776	580	7.0	-	-	-	-	-	-	260	40	85	ND	-	-	-	0.02	-	-	-	-	-	-
MW-31	9/30/2009	BSK	780	510	7.8	-	-	-	-	-	-	250	40	105	<2	-	-	-	-	-	-	-	-	-	-
MW-31	10/6/2010	SSC	810	560	6.9	-	-	-	-	-	-	250	39	95	<2	-	-	-	-	-	-	-	-	-	-
MW-31	5/19/2011	SSC	800	550	6.9	-	-	-	-	-	-	260	38	83	<2.2	-	-	-	-	-	-	-	-	-	-
MW-31	9/21/2011	SSC	790	540	6.8	-	-	-	-	-	-	240	39	82	<2.2	-	-	-	-	-	-	-	-	-	-
MW-31	3/30/2012	BCL	777	560	7.41	-	-	-	-	-	-	240	36	106	<0.4	-	-	-	-	-	-	-	-	-	-
MW-31	10/4/2012	BCL	654	440	7.2	-	-	-	-	-	-	200	28	100	<0.4	-	-	-	-	-	-	-	-	-	-
MW-31	5/7/2013	BCL	598	410	7.4	-	-	-	-	-	-	180	24	81	0.81	-	-	-	-	-	-	-	-	-	-
MW-31	10/24/2013	BCL	609	420	7.2	-	-	-	-	-	-	180	29	84	<0.4	-	-	-	-	-	-	-	-	-	-
MW-31	5/16/2014	BCL	654	440	7.8	-	-	-	-	-	-	180	35	89	<0.4	-	-	-	-	-	-	-	-	-	-
MW-31	10/17/2014	BCL	677	430	7.1	-	-	-	-	-	-	190	38	85	ND	-	-	-	-	-	-	-	-	-	-
MW-32	10/11/1991	BCL	260	200	7.3	-	0.8	26	6.5	17	2.3	50	5	-	-	-	-	-	-	-	-	-	-	-	-
MW-32	3/19/1992	UNK	260	185	7.5	-	-	26	6.1	14.5	2.3	47	5	79.1	-	-	-	-	-	-	0.057	0.049	-	-	-
MW-32	10/26/1992	UNK	280	195	7.4	-	-	27	6.5	151	2.4	53	5	79.1	-	0.07	-	-	-	-	-	0.047	-	-	-
MW-32	3/5/1993	UNK	280	185	7.4	-	-	27	6.8	15.1	2.3	53	5	77.4	-	0.08	-	-	-	-	0.083	0.044	-	-	-
MW-32	9/24/1993	UNK	290	185	7.3	-	-	26	6.5	15.6	2.4	49	6	80.9	-	0.08	-	-	-	-	-	0.058	-	-	-
MW-32	4/12/1994	UNK	259	175	7.4	-	-	26	5.9	14.5	2.4	51	5	73	-	0.07	-	-	-	-	-	0.077	-	-	-
MW-32	9/23/1994	UNK	267	180	7.4	-	-	22	7.2	16.9	2.5	52	5	78.3	-	0.06	-	-	-	-	-	0.072	-	-	-
MW-32	10/18/1995	UNK	283	230	7.5	-	-	27	7.1	16	2.5	60	6	82.6	-	0.08	-	-	-	-	-	0.066	-	-	-
MW-32	4/8/1996	UNK	266	-	8.0	-	-	26	5.3	19.1	2.2	51	6	84.3	-	0.08	-	-	-	-	-	0.032	-	-	-
MW-32	10/9/1996	UNK	261	160	8.0	-	-	26	6.2	16.7	2.4	47	5	82.6	-	0.08	-	-	-	-	-	0.035	-	-	-
MW-32	6/9/1997	UNK	281	192	7.4	-	-	27	7.1	15.6	2.2	55	6	67	37.2	0.08	-	-	-	-	-	-	-	-	-
MW-32	3/26/1998	UNK	460	-	7.4	-	-	66	15	23	2.9	63	4	52	-	-	-	-	0.06	-	-	0.02	-	-	-
MW-32	8/29/1998	UNK	490	330	7.5	-	-	60	14	21	7.2	160	9	58	ND	ND	-	ND	ND	-	ND	0.04	-	-	-
MW-32	4/22/1999	BSK	420	310	6.8	54	0.6	48	12	18	3	140	7	66	<0.2	<0.3	-	<0.1	<0.05	-	<0.05	0.12	-	-	-
MW-32	5/20/2000	BSK	280	170	6.9	46	0.7	28	6.7	15	2	70	6	56	<0.6	<0.3	-	<0.1	<0.05	-	<0.05	0.09	-	-	-
MW-32	12/18/2000	BSK	340	210	7.2	56	0.7	30	7.5	17	2	92	7	68	<0.6	<0.3	-	<0.1	<0.05	-	<0.05	0.13	-	-	-
MW-32	6/5/2001	BSK	290	220	6.5	46	0.8	27	7.1	19	3	84	7	56	<0.6	<0.3	-	<0.1	<0.05	-	<0.05	0.1	-	-	-
MW-32	6/15/2001	UNK	290	220	6.5	46	-	27	7.1	19	3	84	7	46	ND	ND	-	ND	ND	-	ND	0.1	-	-	-
MW-32	10/3/2001	UNK	310	-	6.7	48	-	27	6.8	17	ND	80	8	48	3.5	ND	-	ND	ND	-	ND	0.1	-	-	-
MW-32	5/2/2002	BSK	290	160	6.3	48	-	20	4.9	14	2	50	6	48	<0.4	<0.2	-	<0.1	<0.05	-	<0.05	0.08	-	-	-
MW-32	12/13/2002	UNK	280	170	6.7	48	-	24	6.1	15	2	68	6	48	ND	ND	-	ND	ND	-	ND	0.11	-	-	-
MW-32	3/23/2003	BSK	250	170	6.8	48	-	21	5.4	17	ND	60	6	-	-	ND	-	ND	ND	-	ND	0.1	-	-	-
MW-32	10/24/2003	BSK	230	170	7.6	52	-	21	5.7	16	3	54	5	-	-	ND	-	ND	ND	-	ND	0.11	-	-	-
MW-32	4/1/2004	UNK	280	200	7.6	55	-	28	7.1	20	3	74	6	55	ND	ND	-	ND	ND	-	ND	0.16	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
SHALLOW (Meyers Farm)																									
MF-1	10/20/2009	BCL	1250	780	7.54	370	-	46	26	210	4.9	93	170	450	<0.4	-	9.8	0.28	0.12	<0.002	1.5	0.77	-	-	0.0067
MF-1	10/20/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.95	<0.4	-
MF-1	5/12/2010	BCL	1290	840	7.73	360	-	45	25	210	4.7	85	160	440	0.69	-	-	-	-	<0.002	1.1	0.64	-	-	<0.005
MF-1	9/14/2010	BCL	492	310	7.53	92	-	13	7.3	84	3.4	51	62	110	0.071	-	2	0.27	0.033	<0.002	0.15	0.059	-	-	<0.005
MF-1	9/14/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.75	<0.4	-
MF-1	4/19/2011	BCL	535	330	7.5	85	-	18	10	76	5.3	53	77	100	0.9	-	-	-	-	<0.002	0.3	0.095	-	-	<0.005
MF-1	8/31/2011	BCL	301	170	7.67	79	-	8.1	4.2	49	3.8	21	28	97	<0.4	-	<2	0.23	0.023	<0.002	0.18	0.034	-	-	<0.005
MF-1	8/31/2011	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
MF-1	3/29/2012	BCL	486	270	7.73	75	-	29	11	62	6.2	45	66	91	3.5	-	-	-	-	<0.002	0.081	0.023	-	-	<0.005
MF-1	10/3/2012	BCL	760	470	7.66	200	-	34	16	110	5.1	55	91	293	3.6	-	<2	0.21	0.081	0.0024	0.38	0.45	6	-	<0.005
MF-1	10/3/2012	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
MF-1	5/7/2013	BCL	674	430	7.47	86	-	37	15	78	5.6	110	94	110	5	-	-	-	-	<0.002	0.099	0.055	-	-	<0.005
MF-1	5/15/2014	BCL	1460	880	7.4	-	-	-	-	-	-	94	230	410	1.9	-	-	-	-	-	-	-	-	-	-
MF-2	10/27/2000	TL	1700	1000	-	-	-	-	-	-	-	-	220	-	-	-	-	0.27	-	-	-	-	-	<5	-
MF-2	3/26/2002	FGL	2450	1500	7.1	670	8	93	37	361	7	153	310	810	<0.4	<0.1	<10	0.29	0.243	<0.01	0.16	1	-	<10	<0.02
MF-2	4/23/2002	UNK	2300	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MF-2	9/17/2002	TL	2300	1300	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MF-2	12/13/2002	UNK	2300	1300	7.6	560	-	95	39	300	5	180	310	560	ND	ND	-	0.3	0.2	-	ND	1.2	-	-	-
MF-2	1/3/2003	TL	-	1100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MF-2	1/13/2003	TL	2500	1100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MF-2	4/12/2003	BSK	2400	1400	7.5	610	-	110	49	300	7	190	350	610	<0.2	<3	-	0.2	0.18	-	<0.05	1.3	-	-	-
MF-2	9/30/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<3	-	-	-	-	-	3.9	<0.4	-
MF-2	9/30/2003	TL	2500	1600	7.1	570	-	110	48	400	17	190	330	700	<0.4	-	-	0.27	0.2	<0.05	0.11	1.2	-	-	<0.05
MF-2	12/31/2003	TL	2200	1400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MF-2	3/5/2004	TL	2100	1400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MF-2	4/2/2004	UNK	2200	1400	7.7	580	-	110	44	340	8	230	300	580	ND	ND	-	0.3	0.11	-	ND	1.1	-	-	-
MF-2	11/17/2004	BSK	1900	1200	7.7	490	-	100	46	280	7	250	230	490	<0.2	<0.1	-	0.2	0.08	-	<0.05	1.1	-	-	-
MF-2	3/3/2005	TL	220	1300	-	-	-	-	-	-	-	-	-	-	-	-	-	0.27	-	-	-	1	5.3	-	-
MF-2	3/23/2005	UNK	2200	1300	-	-	-	-	-	-	-	-	-	-	-	-	-	0.27	-	-	-	1	5.3	-	-
MF-2	8/10/2005	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<6	-	-	-	-	-	5.6	<0.4	-
MF-2	8/10/2005	TL	1600	1100	7.1	430	-	73	31	290	13	180	210	530	3.5	-	-	0.25	0.088	<0.005	<0.1	0.8	-	-	<0.005
MF-2	9/1/2005	UNK	1600	1100	7.1	430	-	73	31	290	13	180	210	530	-	-	ND	0.25	0.088	-	ND	0.8	5.6	ND	ND
MF-2	4/20/2006	TL	1600	1000	7.0	400	-	83	41	240	14	210	180	-	<2	-	-	-	-	<0.005	<0.1	1	-	-	<0.005
MF-2	9/26/2006	TL	1200	780	7.3	300	-	56	27	180	11	140	130	-	11	-	<10	0.2	0.19	<0.005	0.14	0.45	7.4	<20	<0.005
MF-2	3/28/2007	TL	920	560	7.3	230	-	34	15	160	8.7	110	110	280	-	-	ND	0.22	0.096	ND	ND	0.23	6.5	ND	ND
MF-2	9/24/2007	TL	840	510	7.2	200	-	38	17	130	7	93	100	240	-	-	ND	0.25	0.094	ND	0.18	0.61	-	-	ND
MF-2	7/10/2008	BCL	977	550	7.46	220	-	51	22	130	5.7	85	120	270	-	-	-	-	-	0.0027	0.24	0.62	-	-	0.0078
MF-2	9/3/2008	BCL	864	510	7.3	-	-	44	19	100	4.3	92	110	240	-	-	ND	0.26	0.083	0.0028	0.064	0.42	-	-	0.0088
MF-2	9/3/2008	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.45	<0.4	-
MF-2	4/2/2009	BCL	1090	730	7.29	300	-	60	26	160	5.5	92	140	360	-	-	-	-	-	<0.002	0.11	0.41	-	-	<0.005
MF-2	10/20/2009	BCL	1560	960	7.37	390	-	85	38	230	6.7	150	220	470	<0.4	-	<2	0.24	0.18	<0.002	0.48	0.92	-	-	0.0059
MF-2	10/20/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.15	<0.4	-
MF-2	5/20/2010	BCL	1560	1000	7.39	370	-	92	41	210	7.7	190	210	450	0.23	-	-	-	-	0.002	0.16	0.75	-	-	0.0074
MF-2	9/14/2010	BCL	1400	920	7.31	260	-	79	37	200	6.1	270	160	320	2.7	-	<2	0.26	0.088	<0.002	0.13	0.98	-	-	0.0067
MF-2	9/14/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.1	<0.4	-
MF-2	4/19/2011	BCL	1030	620	7.34	210	-	56	27	110	5.6	150	130	250	2.7	-	-	-	-	<0.002	0.12	0.65	-	-	0.0057
MF-2	8/31/2011	BCL	1270	820	7.34	150	-	58	25	200	9	270	120	190	61	-	<2	0.23	0.059	0.0022	0.15	0.23	-	-	<0.005

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/LI)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
SHALLOW (Meyers Farm)																									
MF-4	9/17/2002	TL	2900	1600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MF-4	12/13/2002	UNK	2900	1500	7.5	1200	-	150	34	300	36	ND	280	1200	ND	ND	-	0.3	0.27	-	0.7	1.8	-	-	-
MF-4	1/3/2003	TL	-	1500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MF-4	4/12/2003	BSK	2600	1400	7.3	1100	-	150	36	240	39	<60	270	1100	<0.2	<3	-	0.3	0.36	-	<0.05	2.2	-	-	-
MF-4	9/30/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16	-	-	-	-	-	1.2	<0.4	-
MF-4	9/30/2003	TL	2700	1600	7.1	1200	-	180	45	350	62	7.9	270	1500	0.76	-	-	0.3	0.43	<0.05	11	2.8	-	-	<0.05
MF-4	3/4/2004	TL	2600	1500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MF-4	4/2/2004	UNK	2400	1400	7.6	1000	-	160	42	300	36	ND	260	1000	ND	ND	-	0.4	0.24	-	1.8	2.6	-	-	-
MF-4	11/17/2004	BSK	1900	1100	7.7	760	-	100	30	250	26	24	200	760	<0.2	0.5	-	0.4	0.13	-	<0.05	1.8	-	-	-
MF-4	3/2/2005	TL	1500	850	-	-	-	-	-	-	-	-	-	-	-	-	-	0.31	-	-	-	1.1	<5	-	-
MF-4	8/10/2005	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	75	-	-	-	-	-	2.1	<0.4	-
MF-4	8/10/2005	TL	1300	890	7.2	500	-	72	20	220	28	57	150	610	<2	-	-	0.29	0.17	<0.005	9	1.3	-	-	<0.005
MF-4	9/1/2005	UNK	1300	890	7.2	500	-	72	20	220	28	57	150	610	-	-	74	0.29	0.17	ND	9	1.3	2	ND	ND
MF-4	4/20/2006	TL	1400	820	7.2	490	-	61	16	220	32	49	150	-	<2	-	-	-	-	<0.005	5.9	1.1	-	-	<0.005
MF-4	9/26/2006	TL	1300	770	7.3	450	-	56	15	190	26	41	130	-	<10	-	70	0.33	0.12	<0.005	6.8	1	5.3	<20	0.0057
MF-4	3/28/2007	TL	1400	820	7.3	520	-	76	21	210	23	23	150	630	-	-	73	0.31	0.17	ND	8.1	1.5	5.1	ND	ND
MF-4	9/25/2007	TL	1500	880	7.3	600	-	78	22	230	33	18	150	740	-	-	45	0.33	0.091	ND	8.1	1.4	-	-	ND
MF-4	4/6/2008	BCL	1380	880	7.56	500	-	73	21	190	19	31	140	610	<0.4	-	-	-	-	<0.002	8.4	1.5	-	-	0.0067
MF-4	9/3/2008	BCL	2110	1200	7.45	-	-	130	36	280	30	3.8	210	1100	-	-	64	0.16	0.33	<0.002	11	2	-	-	0.0062
MF-4	9/3/2008	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.03	<0.4	-
MF-4	4/2/2009	BCL	2000	1300	7.43	820	-	120	34	270	28	5.9	200	1000	-	-	-	-	-	<0.002	12	2	-	-	0.005
MF-4	10/21/2009	BCL	1830	990	7.36	730	-	100	28	290	37	2.8	180	890	<0.4	-	56	0.38	0.27	<0.002	9.6	1.3	-	-	0.005
MF-4	10/21/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<0.4	-
MF-4	5/12/2010	BCL	1750	980	7.64	650	-	82	24	230	27	23	190	790	<0.4	-	-	-	-	<0.002	6.2	1.1	-	-	<0.005
MF-4	9/14/2010	BCL	1290	780	7.59	470	-	54	15	220	22	31	140	570	<0.4	-	49	0.4	0.15	<0.002	5.1	0.71	-	-	<0.005
MF-4	9/14/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.1	<0.4	-
MF-4	4/19/2011	BCL	1640	1200	7.5	610	-	83	24	250	24	28	150	740	<0.4	-	-	-	-	<0.002	8.4	1.4	-	-	<0.005
MF-4	8/31/2011	BCL	1210	700	7.62	350	-	56	16	180	19	65	140	420	<0.4	-	46	0.32	0.14	<0.002	4.5	1.1	-	-	<0.005
MF-4	8/31/2011	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
MF-4	3/29/2012	BCL	1790	1000	7.37	620	-	100	28	250	25	40	180	750	1.3	-	-	-	-	<0.002	8.1	2	-	-	<0.005
MF-4	10/3/2012	BCL	1200	720	7.7	320	-	51	14	180	17	100	140	476	<0.4	-	60	0.3	0.15	<0.002	6.5	0.86	5	-	<0.005
MF-4	10/3/2012	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
MF-4	5/7/2013	BCL	1190	720	7.63	390	-	56	16	180	17	51	130	470	0.62	-	-	-	-	<0.002	3.4	1.1	-	-	<0.005
MF-4	5/15/2014	BCL	1320	780	7.6	-	-	-	-	-	-	68	140	490	<0.4	-	-	-	-	-	-	-	-	-	-
MF-5	3/27/2002	FGL	2750	1710	6.9	720	7.7	109	55	395	10	270	240	870	<0.4	0.4	<10	0.37	0.216	<0.01	5.85	1.47	-	<10	<0.02
MF-5	4/23/2002	TL	1400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MF-5	10/1/2002	UNK	3000	1800	7.0	770	-	120	56	460	19	300	330	940	-	-	ND	0.37	0.28	ND	8.6	1.4	-	ND	ND
MF-5	10/10/2002	TL	3000	1800	7.0	770	-	120	56	460	19	300	330	940	<2	-	<10	0.37	0.28	<0.05	8.6	1.4	-	<10	<0.05
MF-5	12/13/2002	UNK	2500	1500	7.2	540	-	89	44	340	9	330	310	540	ND	ND	-	0.4	0.16	-	ND	1.1	-	-	-
MF-5	1/6/2003	UNK	2100	1300	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MF-5	1/13/2003	TL	2100	1300	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MF-5	4/12/2003	BSK	1500	900	7.6	450	-	43	43	190	3	83	200	450	<0.2	<3	-	0.4	0.1	-	<0.05	0.59	-	-	-
MF-5	9/30/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<3	-	-	-	-	-	7.2	<0.4	-
MF-5	9/30/2003	TL	1300	860	7.0	420	-	39	40	230	4.7	80	170	510	<0.4	-	-	0.42	0.1	<0.05	3.6	0.48	-	-	<0.05
MF-5	3/3/2004	UNK	700	410	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MF-5	3/31/2004	TL	700	410	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MF-5	4/2/2004	UNK	670	410	7.7	120	-	18	8.3	97	6	52	100	120	ND	ND	-	0.3	ND	-	0.14	0.24	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
SHALLOW (Meyers Farm)																									
MF-6	3/28/2007	TL	850	510	7.0	240	-	17	10	160	4.8	50	110	290	-	-	ND	0.2	0.098	ND	2.7	0.33	5.4	ND	ND
MF-6	9/25/2007	TL	1400	870	7.1	410	-	30	17	290	4.6	66	170	500	-	-	ND	0.28	0.046	ND	4	0.55	-	-	ND
MF-6	4/6/2008	BCL	1460	830	7.34	390	-	35	21	290	2.8	98	180	470	<0.4	-	-	-	-	<0.002	5.6	0.56	-	-	0.0056
MF-6	9/3/2008	BCL	2150	1300	7.26	-	-	44	27	410	2.5	85	280	850	-	-	7.9	0.33	0.24	0.031	6	0.86	-	-	0.0083
MF-6	9/3/2008	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.75	<0.4	-
MF-6	4/2/2009	BCL	1850	1400	7.33	610	-	39	23	390	2.5	92	230	740	-	-	-	-	-	<0.002	4.9	0.6	-	-	0.0056
MF-6	10/21/2009	BCL	1520	1100	7.38	450	-	38	19	310	5.3	84	190	550	<0.4	-	4.3	0.33	0.14	0.0026	4	0.55	-	-	0.0058
MF-6	10/21/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.3	<0.4	-
MF-6	5/12/2010	BCL	1820	1100	7.5	550	-	36	22	360	2.3	87	230	680	<0.4	-	-	-	-	<0.002	5	0.57	-	-	<0.005
MF-6	9/14/2010	BCL	444	280	7.39	86	-	14	5.9	69	6.6	42	53	100	<0.4	-	7.9	0.25	0.046	<0.002	1.7	0.14	-	-	0.0051
MF-6	9/14/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13.1	<0.4	-
MF-6	4/19/2011	BCL	580	430	7.45	150	-	12	6.5	100	2.4	35	57	190	<0.4	-	-	-	-	0.0025	2.1	0.18	-	-	<0.005
MF-6	8/31/2011	BCL	1270	800	7.4	380	-	21	13	260	2.3	55	150	460	<0.4	-	6.8	0.36	0.11	<0.002	3.2	0.34	-	-	<0.005
MF-6	8/31/2011	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
MF-6	3/29/2012	BCL	1240	720	7.33	350	-	20	12	270	1.9	57	130	430	<0.4	-	-	-	-	<0.002	3	0.3	-	-	<0.005
MF-6	10/3/2012	BCL	1280	830	7.51	350	-	27	16	250	2.1	80	160	512	<0.4	-	5.7	0.26	0.12	<0.002	3.6	0.4	6.8	-	<0.005
MF-6	10/3/2012	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
MF-6	5/7/2013	BCL	855	520	7.43	150	-	41	19	120	4.3	120	120	180	<0.4	-	-	-	-	<0.002	3.7	0.43	-	-	<0.005
MF-6	5/15/2014	BCL	1310	800	7.5	-	-	-	-	-	-	100	160	430	<0.9	-	-	-	-	-	-	-	-	-	-
MF-7	10/1/2002	UNK	4100	2600	7.3	1000	-	75	69	760	18	470	410	1200	-	-	ND	0.88	0.2	ND	1.6	0.65	-	ND	ND
MF-7	10/11/2002	TL	4100	2600	7.3	1000	-	75	69	760	18	470	410	1200	-	-	<10	0.2	0.88	<0.05	1.6	0.7	-	<10	<0.05
MF-7	12/13/2002	UNK	4200	2600	7.8	1100	-	65	71	730	8	420	460	1100	66.4	ND	-	0.9	0.1	-	ND	0.55	-	-	-
MF-7	1/6/2003	UNK	3600	2500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MF-7	1/13/2003	TL	3600	2500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MF-7	4/12/2003	BSK	3200	2000	7.6	1200	-	36	38	340	6	160	280	1200	<0.2	<2	-	0.8	0.06	-	<0.05	0.32	-	-	-
MF-7	9/30/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<3	-	-	-	-	-	30.2	<0.4	-
MF-7	9/30/2003	TL	3200	2100	7.7	1200	-	33	38	740	18	240	240	1500	<0.4	-	-	0.75	0.07	<0.05	0.58	0.34	-	-	<0.05
MF-7	3/4/2004	TL	3200	2100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MF-7	4/2/2004	UNK	2600	1700	7.6	440	-	23	19	530	4	340	250	440	239.1	ND	-	0.8	ND	-	ND	0.15	-	-	-
MF-7	11/17/2004	BSK	1300	800	7.8	240	-	17	14	250	4	190	130	240	12	0.6	-	0.5	<0.05	-	<0.05	0.08	-	-	-
MF-7	3/3/2005	TL	800	490	-	-	-	-	-	-	-	-	-	-	-	-	-	0.46	-	-	-	0.021	21	-	-
MF-7	3/23/2005	UNK	800	490	-	-	-	-	-	-	-	-	-	-	-	-	-	0.46	-	-	-	0.021	21	-	-
MF-7	8/9/2005	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<6	-	-	-	-	-	18.5	1.3	-
MF-7	8/9/2005	TL	980	680	7.2	230	-	3.8	3.2	250	4.3	110	110	280	<2	-	-	0.44	0.015	0.0061	<0.1	0.012	-	-	0.0056
MF-7	8/30/2005	UNK	980	680	7.2	230	-	3.8	3.2	250	4.3	110	110	280	-	-	ND	0.44	0.015	ND	ND	0.012	19	-	0.0056
MF-7	4/20/2006	TL	670	480	7.3	190	-	2.7	2.4	170	3.8	60	67	-	17	-	-	-	-	0.0068	1.1	0.019	-	-	0.005
MF-7	9/26/2006	TL	950	630	7.3	260	-	2.4	2.2	210	4.1	77	72	-	35	-	<10	0.47	0.029	0.0081	3.4	0.29	27	<20	0.0054
MF-7	3/28/2007	TL	580	400	7.5	200	-	1.3	1.3	140	2.9	35	32	250	-	-	ND	0.33	0.023	0.0061	2.9	0.24	20	ND	ND
MF-7	9/24/2007	TL	500	310	7.1	97	-	9.4	9.3	85	5	52	67	120	-	-	ND	0.18	0.031	ND	1.8	0.27	-	-	ND
MF-7	4/6/2008	BCL	770	430	7.65	150	-	19	17	120	3.6	87	98	180	0.57	-	-	-	-	0.0026	2.1	0.2	-	-	0.0082
MF-7	9/3/2008	BCL	837	480	7.48	-	-	39	28	83	5.3	100	-	190	-	-	ND	0.32	0.083	0.0022	1.8	1	-	-	0.013
MF-7	9/3/2008	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.95	<0.4	-
MF-7	4/2/2009	BCL	794	510	7.33	160	-	37	30	97	5.3	110	100	200	-	-	-	-	-	<0.002	3.1	0.58	-	-	<0.005
MF-7	10/21/2009	BCL	946	580	7.33	180	-	52	39	100	6.3	170	110	220	<0.4	-	2.9	0.26	0.15	<0.002	4.7	0.65	-	-	0.0064
MF-7	10/21/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	<0.4	-
MF-7	5/12/2010	BCL	841	510	6.85	84	-	27	23	120	6.1	140	130	100	4.6	-	-	-	-	0.0023	13	0.9	-	-	0.0052
MF-7	9/14/2010	BCL	652	420	7.22	160	-	11	9.1	120	3.1	63	61	200	4.1	-	2.6	0.41	0.031	0.0033	2.1	0.18	-	-	0.0062

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Cations				Anions					Trace Elements								
								Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
SHALLOW (Meyers Farm)																									
MF-9	1/6/2003	UNK	2300	1400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MF-9	1/13/2003	TL	2300	1400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MF-9	3/23/2003	BSK	-	1400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MF-9	4/12/2003	BSK	2100	1400	7.6	460	-	32	16	350	4	310	230	460	<0.2	<2	-	0.6	0.07	-	<0.05	0.53	-	-	-
MF-9	9/29/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<3	-	-	-	-	-	32.6	<0.4	-
MF-9	9/29/2003	TL	2400	1500	7.3	280	-	54	27	460	22	410	250	340	<0.4	-	-	0.61	0.09	<0.05	0.11	1	-	-	<0.05
MF-9	3/4/2004	TL	2200	1400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MF-9	4/2/2004	UNK	2200	1400	8.1	560	-	47	23	450	6	260	280	560	2.2	ND	-	0.6	0.09	-	ND	0.88	-	-	-
MF-9	11/17/2004	BSK	2600	1600	7.9	780	-	63	34	510	7	220	330	780	<0.2	<0.1	-	0.6	0.08	-	<0.05	1.1	-	-	-
MF-9	3/2/2005	TL	3300	2000	-	-	-	-	-	-	-	-	-	-	-	-	-	0.67	-	-	-	1.8	25	-	-
MF-9	3/21/2005	UNK	3300	2000	-	-	-	-	-	-	-	-	-	-	-	-	-	0.67	-	-	-	1.8	25	-	-
MF-9	8/9/2005	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<6	-	-	-	-	-	26.1	<0.4	-
MF-9	8/9/2005	TL	3200	2100	7.0	950	-	95	42	630	17	300	380	1200	<2	-	-	0.7	0.1	<0.005	0.8	1.4	-	-	<0.005
MF-9	8/30/2005	UNK	3200	2100	7.0	950	-	95	42	630	17	300	380	1200	-	-	ND	0.7	0.1	ND	0.8	1.4	26	ND	ND
MF-9	4/20/2006	TL	3100	2100	7.3	1000	-	67	33	700	20	280	320	-	<2	-	-	-	-	<0.01	1.6	1.4	-	-	<0.01
MF-9	9/26/2006	TL	2800	1800	7.4	920	-	54	24	620	16	190	290	-	<20	-	<20	0.8	0.074	<0.01	2.6	0.88	56	<40	0.013
MF-9	3/28/2007	TL	2600	1600	7.5	820	-	49	20	550	15	170	290	1000	-	-	ND	0.72	0.073	ND	1.2	0.65	43	ND	ND
MF-9	9/24/2007	TL	1500	860	7.7	400	-	13	6.7	330	9.1	150	120	490	-	-	ND	0.56	0.031	ND	0.87	0.29	-	-	ND
MF-9	4/6/2008	BCL	1540	1000	8.06	400	-	14	7	370	5.3	180	150	490	<0.4	-	-	-	-	<0.002	1.1	0.27	-	-	0.0054
MF-9	9/3/2008	BCL	2000	1200	7.85	-	-	22	12	440	5.4	8.3	8.3	680	-	-	2	0.53	0.059	ND	1.7	0.53	-	-	0.0083
MF-9	9/3/2008	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	26.2	<0.4	-
MF-9	4/2/2009	BCL	2200	1400	7.7	630	-	29	16	520	5.7	250	230	770	-	-	-	-	-	<0.002	1.7	0.63	-	-	<0.005
MF-9	10/21/2009	BCL	3010	2000	7.44	660	-	53	33	650	7.9	470	380	800	<0.9	-	2.1	0.93	0.14	0.0022	4.8	1.2	-	-	0.0052
MF-9	10/21/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21.6	<0.4	-
MF-9	5/12/2010	BCL	2960	1900	7.7	620	-	50	33	590	6.7	470	380	760	<0.4	-	-	-	-	0.0071	6.1	1.3	-	-	<0.005
MF-9	9/14/2010	BCL	3120	2100	7.56	830	-	44	32	710	7.6	410	340	1000	<0.9	-	<2	0.93	0.099	<0.002	3.8	1.1	-	-	<0.005
MF-9	9/14/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	42	<0.4	-
MF-9	4/19/2011	BCL	1150	700	8.1	300	-	4.3	3	250	2.3	110	100	360	<0.4	-	-	-	-	<0.002	1.2	0.11	-	-	0.007
MF-9	8/31/2011	BCL	992	610	8.05	190	-	3.2	2.3	230	2.5	130	110	240	<0.4	-	<2	0.36	0.018	0.0021	1.3	0.08	-	-	<0.005
MF-9	8/31/2011	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
MF-9	3/29/2012	BCL	1060	660	8.05	210	-	3.6	2.4	240	2.1	130	110	260	<0.4	-	-	-	-	<0.002	1	0.083	-	-	<0.005
MF-9	10/3/2012	BCL	885	570	8.18	210	-	2.7	1.8	200	1.8	110	86	305	<0.4	-	<2	0.36	0.018	<0.002	1.2	0.071	16	-	<0.005
MF-9	10/3/2012	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
MF-9	5/7/2013	BCL	865	520	8.21	190	-	2.4	1.7	190	1.7	100	92	230	0.85	-	-	-	-	<0.002	0.26	0.049	-	-	<0.005
MF-9	5/15/2014	BCL	1500	930	7.9	-	-	-	-	-	-	220	170	380	<0.9	-	-	-	-	-	-	-	-	-	-
EW-1	6/25/2004	TL	1100	680	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EW-1	9/13/2004	FGL	1040	650	6.9	-	-	25	16	175	2	133	120	240	<0.4	-	<2	0.3	0.06	0.004	1.64	0.37	-	-	<0.01
EW-1	9/13/2004	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.3	<0.4	-
EW-1	8/1/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.3	<0.4	-
EW-1	8/1/2007	TL	760	490	7.4	210	-	22	13	150	3.5	66	80	260	<4	-	<10	0.31	0.052	<0.005	1.4	0.42	12	<20	<0.005
EW-1	5/9/2008	BCL	660	440	7.3	-	-	24	16	110	3.3	-	60	180	-	-	ND	0.26	0.054	ND	2.2	0.56	-	-	ND
EW-1	5/9/2008	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.33	<0.4	-
EW-1	11/25/2008	BCL	807	480	7.2	130	-	33	22	110	2.7	130	88	160	-	-	1.1	0.25	0.07	0.0074	10	0.99	11	ND	0.054
EW-1	3/11/2009	BCL	1090	800	7.62	240	-	45	27	190	2.6	170	120	290	-	-	ND	0.32	0.091	<0.002	4.1	1.1	-	-	<0.005
EW-1	3/11/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	ND	-
EW-1	8/14/2009	BCL	1100	720	7.73	270	-	34	19	220	2.5	130	150	320	-	-	ND	0.35	0.078	<0.002	1.7	0.63	-	-	0.0061
EW-1	8/14/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.7	ND	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
SHALLOW (Meyers Farm)																									
EW-6	4/27/2012	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
EW-6	5/10/2013	BCL	691	440	7.17	110	-	28	15	96	5.7	77	100	140	<0.4	-	<2	0.24	0.078	<0.002	4	0.49	5.6	-	<0.005
EW-7	11/12/2008	BCL	1330	800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EW-7	3/11/2009	BCL	1550	860	7.8	480	-	52	14	300	2.6	55	200	590	-	-	ND	0.21	0.14	<0.002	0.54	0.51	-	-	<0.005
EW-7	3/11/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	ND	ND	-
EW-7	8/14/2009	BCL	1410	900	7.83	450	-	43	8.4	290	2.2	28	210	550	-	-	ND	0.21	0.096	ND	0.2	0.41	-	-	0.0069
EW-7	8/14/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.65	ND	-
EW-7	4/24/2012	BCL	1630	1000	7.92	520	-	66	14	310	3	38	-	630	<0.4	-	-	-	-	<0.002	0.41	0.78	1.4	-	<0.005
EW-7	4/24/2012	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.4	-
EW-7	5/10/2013	BCL	1510	940	7.69	500	-	62	13	310	2.9	39	200	610	<0.9	-	<2	0.22	0.14	<0.002	0.37	0.53	1.9	-	<0.005
EW-8	11/8/2008	BCL	1130	680	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EW-8	3/11/2009	BCL	1090	720	7.9	280	-	48	16	180	2.2	69	160	340	-	-	ND	0.23	0.091	<0.002	0.35	0.52	-	-	0.074
EW-8	3/11/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	ND	ND	-
EW-8	8/14/2009	BCL	1030	670	7.92	280	-	38	10	190	1.8	65	150	350	-	-	ND	0.21	0.07	0.0037	0.27	0.52	-	-	0.0072
EW-8	8/14/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.95	ND	-
EW-8	4/27/2012	BCL	1170	730	7.91	270	-	65	18	200	2.7	87	160	320	<0.4	-	-	-	-	<0.002	0.41	0.7	2.2	-	<0.005
EW-8	4/27/2012	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
EW-8	5/10/2013	BCL	1170	740	7.83	290	-	59	15	210	2.5	79	170	360	<0.9	-	<2	0.24	0.099	<0.002	0.36	0.58	2	-	<0.005
DEEP (Spreckels)																									
MW-7	5/6/1983	BCL	960	657	7.8	-	-	54	36	102	7	123	157	192	<1	-	<10	-	-	-	3.2	1	-	-	-
MW-7	5/29/1983	UNK	960	657	7.8	-	-	54	36	102	7.4	123	157	192	-	-	-	-	-	-	3.2	1	-	-	-
MW-7	11/24/1983	UNK	3000	1837	7.8	-	-	63	12.1	630	5.5	10	406	1221	4	-	-	-	-	-	3.4	1.2	-	-	-
MW-7	12/2/1983	UNK	3100	1730	8.0	-	-	6	8	700	6	10	414	1209	-	-	-	-	-	-	0.14	0.94	-	-	-
MW-7	3/6/1984	UNK	3000	1740	7.6	-	-	46	10.2	620	3.5	13	389	1140	-	-	-	-	-	-	-	-	-	-	-
MW-7	5/22/1984	UNK	2800	1663	7.6	-	-	9	6.5	610	3	9	367	1064	12	-	-	-	-	-	1.6	0.065	-	-	-
MW-7	7/19/1984	UNK	2600	1590	8.0	-	-	13.5	5.9	600	3.3	10	350	1032	-	-	-	-	-	-	1.9	0.6	-	-	-
MW-7	11/27/1984	UNK	2700	1713	7.6	-	-	14	5.1	590	3.1	8	337	1036	-	-	-	0.14	-	-	0.76	0.44	-	-	-
MW-7	4/23/1985	UNK	2500	1700	7.8	-	-	26	6.1	615	3.6	11	368	1084	-	-	-	-	-	-	-	0.49	-	-	-
MW-7	11/4/1985	UNK	2890	1820	7.7	-	-	27	5.3	570	4.3	-	375	1139	-	-	-	-	-	-	1.7	0.59	-	-	-
MW-7	9/23/1986	UNK	3250	1910	7.9	-	-	50	7.5	690	4.8	19	467	1212	-	-	-	-	-	-	1.6	0.77	-	-	-
MW-7	4/21/1987	UNK	3200	1845	7.8	-	-	36	9	715	4.7	9	441	1269	-	-	-	-	0.31	-	1.4	0.84	-	-	-
MW-7	3/24/1988	UNK	4000	2410	7.3	-	-	92	13	820	6.5	9	536	1620	-	-	-	-	0.51	-	1.9	1.4	-	-	-
MW-7	12/19/1988	UNK	4400	2655	7.5	-	-	106	15	910	6	12	584	1776	-	-	-	-	-	-	5.4	1.6	-	-	-
MW-7	12/12/1989	UNK	5300	3295	7.1	-	-	178	30	970	30	52	663	2194	-	-	-	-	-	-	0.219	2.3	-	-	-
MW-7	4/10/1990	UNK	5300	3310	7.2	-	-	166	27	970	42	30	680	2252	-	-	-	-	-	-	10.56	2.04	-	-	-
MW-7	11/14/1990	UNK	-	2340	6.9	-	-	-	-	-	36	-	576	223	-	-	-	-	0.521	-	0.077	0.338	-	-	-
MW-7	6/20/1991	UNK	6100	3780	7.1	-	-	-	-	-	97	-	835	2743	-	-	-	-	2.95	-	-	-	-	-	-
MW-7	10/29/1991	UNK	6500	3860	6.9	-	-	167	37	1220	116	36	853	2740	1.8	-	-	0.17	2.7	-	15.79	2.24	-	-	-
MW-7	2/24/1992	UNK	6600	4040	7.1	-	-	192	45	1270	106	31	947	2640	-	-	-	0.17	2.8	-	16.6	2.18	-	-	-
MW-7	10/20/1992	UNK	7100	4350	6.9	-	-	204	44	1290	116	-	970	2990	-	-	-	0.23	2.88	-	10.5	2.1	-	-	-
MW-7	3/1/1993	UNK	7100	4240	6.8	-	-	210	53	1330	116	-	1040	3070	-	0.05	-	0.24	3.08	-	18.6	2	-	-	-
MW-7	9/27/1993	UNK	7200	5000	6.7	-	-	203	50	1350	131	-	1040	2950	-	-	-	0.22	3.29	-	7.59	2.31	-	-	-
MW-7	3/10/1994	UNK	7350	4520	6.9	-	-	184	51	1410	179	-	1040	3170	-	-	-	0.19	3.51	-	5.73	1.85	-	-	-
MW-7	9/20/1994	UNK	7070	4600	6.8	-	-	138	48	1350	124	-	1020	2970	-	-	-	0.15	2.64	-	19.7	1.59	-	-	-
MW-7	3/16/1995	UNK	7250	4750	6.7	-	-	180	52	1400	163	-	1050	3120	-	-	-	0.18	2.3	-	0.422	1.34	-	-	-
MW-7	10/10/1995	UNK	6930	4280	7.0	-	-	169	48	1260	116	-	962	2720	-	-	-	0.27	2.24	-	0.41	1.51	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
DEEP (Spreckels)																									
MW-8	2/24/1992	UNK	810	505	8.1	-	-	13.7	1.8	179	1.7	5	76.6	397	-	0.07	-	-	-	-	1.9	0.143	-	-	-
MW-8	10/20/1992	UNK	910	353	8.2	-	-	17.2	2.2	196	2	-	81	410	-	0.06	-	-	-	-	0.254	0.122	-	-	-
MW-8	3/1/1993	UNK	940	575	8.1	-	-	20	2.7	207	2	-	86.3	466	-	0.06	-	-	-	-	2.12	0.189	-	-	-
MW-8	9/27/1993	UNK	950	540	8.1	-	-	17.8	2.5	207	2.2	-	89	463	-	-	-	-	-	-	0.646	0.148	-	-	-
MW-8	3/10/1994	UNK	970	560	8.0	-	-	15.1	2.4	215	2	-	90.5	460	-	-	-	0.19	3.51	-	5.73	1.85	-	-	-
MW-8	9/20/1994	UNK	1050	635	8.1	-	-	19.7	3.1	220	2.3	-	96.1	496	-	-	-	-	-	-	-	0.15	-	-	-
MW-8	3/16/1995	UNK	1000	650	8.1	-	-	16.7	2.6	217	2.2	-	96	478	-	0.05	-	-	-	-	-	0.117	-	-	-
MW-8	10/10/1995	UNK	1000	605	8.2	-	-	14.7	2.2	214	1.9	-	97.5	475	-	0.05	-	-	-	-	-	0.1	-	-	-
MW-8	4/6/1996	UNK	1020	610	8.3	-	-	13.3	2.1	218	1.9	-	97.6	481	-	0.06	-	-	-	-	-	0.092	-	-	-
MW-8	9/30/1996	UNK	979	585	8.77	-	-	12.4	1.9	214	1.9	-	96.6	416	-	0.05	-	-	-	-	-	0.07	-	-	-
MW-8	6/30/1997	UNK	1120	695	8.5	-	-	15.6	2.4	246	2	-	110	465	-	-	-	-	-	-	-	0.092	-	-	-
MW-8	3/23/1998	UNK	1200	800	7.8	-	-	29	4.2	330	3.5	21	160	500	-	-	-	-	0.1	-	-	0.19	-	-	-
MW-8	8/26/1998	UNK	1200	690	8.1	-	-	19	2.7	270	2.4	ND	120	460	ND	ND	-	ND	0.06	-	ND	0.12	-	-	-
MW-8	4/21/1999	BSK	1100	720	8.1	450	15.7	18	2.7	270	2	<30	120	549	<3	<1.5	-	<0.1	0.06	-	<0.05	0.11	-	-	-
MW-8	5/20/2000	BSK	1200	760	7.9	480	13.5	21	3.1	250	<2	<30	140	586	<3	<1.5	-	<0.1	0.06	-	<0.05	0.14	-	-	-
MW-8	12/17/2000	BSK	1300	830	7.8	490	13.9	24	4	280	2	<32	150	598	<3.2	<1.6	-	<0.1	0.07	-	<0.05	0.16	-	-	-
MW-8	6/5/2001	BSK	1300	810	7.8	490	14.2	25	3.9	290	2	<30	160	598	-	<1.5	-	<0.1	0.07	-	<0.05	0.17	-	-	-
MW-8	10/3/2001	UNK	1300	800	7.7	-	-	24	4	290	ND	ND	150	490	ND	ND	-	ND	0.06	-	ND	0.14	-	-	-
MW-8	5/2/2002	BSK	1400	790	8.0	500	-	22	3.6	280	<2	<40	160	500	<4	<2	-	<0.1	0.07	-	<0.05	0.15	-	-	-
MW-8	12/10/2002	BSK	1300	800	7.9	460	-	22	3.4	240	ND	ND	150	-	-	ND	-	0.1	0.08	-	ND	0.14	-	-	-
MW-8	3/22/2003	BSK	1400	820	7.9	470	-	21	3.5	260	ND	ND	160	-	-	ND	-	ND	0.07	-	ND	0.14	-	-	-
MW-8	10/24/2003	BSK	1400	850	8.3	540	-	19	3	270	3	-	150	-	-	ND	-	ND	0.06	-	ND	0.12	-	-	-
MW-8	4/1/2004	UNK	1400	860	8.3	550	-	19	2.8	310	2	ND	170	550	ND	ND	-	ND	0.06	-	ND	0.11	-	-	-
MW-8	11/13/2004	BSK	1500	950	8.3	610	-	19	2.9	330	2	<6	180	740	<2.7	<0.3	-	<0.1	0.07	-	<0.05	0.11	-	-	-
MW-8	4/6/2005	UNK	1500	890	8.3	590	-	17	2.4	360	3	ND	180	580	ND	ND	-	ND	0.07	-	ND	0.1	-	-	-
MW-8	10/13/2005	UNK	1600	920	8.4	590	-	17	2.2	360	ND	ND	170	570	ND	ND	-	0.1	0.07	-	ND	0.1	-	-	-
MW-8	4/19/2006	DL	1571	1005	8.2	621	-	17	46	328	5.4	ND	185	621	<0.1	<0.1	-	0.06	0.06	-	0.03	0.1	-	-	-
MW-8	9/25/2006	UNK	1310	950	8.2	565	-	15.1	1.9	314	2.3	ND	194	565	ND	ND	-	0.06	0.05	-	0.05	0.09	-	-	-
MW-8	3/29/2007	TL	1600	980	7.9	590	-	16	2	370	4.9	<10	170	720	<10.2	<0.5	<10	0.088	0.067	<0.005	-	-	<5	-	<0.005
MW-8	9/23/2007	TL	1600	980	7.8	-	-	-	-	-	-	<20	170	730	<20	-	-	-	-	-	-	-	-	-	-
MW-8	4/5/2008	BCL	1670	1100	8.2	-	-	-	-	-	-	<1	200	744	-	-	-	-	-	-	-	-	-	-	-
MW-8	9/2/2008	BCL	1640	1000	82	-	-	-	-	-	-	5	220	756	<0.9	-	-	-	0.089	-	-	-	-	-	-
MW-8	4/2/2009	UNK	1500	960	8.1	-	-	-	-	-	-	ND	190	570	ND	-	-	-	0.081	-	-	-	-	-	-
MW-8	10/2/2009	BSK	1500	880	8.3	-	-	-	-	-	-	<10	180	659	<5	-	-	-	-	-	-	-	-	-	-
MW-8	10/6/2010	SSC	1600	940	7.8	-	-	-	-	-	-	<10	190	690	<2	-	-	-	-	-	-	-	-	-	-
MW-8	5/19/2011	SSC	1700	1000	7.8	-	-	-	-	-	-	<10	200	600	<2.2	-	-	-	-	-	-	-	-	-	-
MW-8	9/21/2011	SSC	1600	920	7.9	-	-	-	-	-	-	<10	190	560	<2.2	-	-	-	-	-	-	-	-	-	-
MW-8	3/30/2012	BCL	1600	960	8.3	-	-	-	-	-	-	1.1	200	634	<0.9	-	-	-	-	-	-	-	-	-	-
MW-8	10/4/2012	BCL	1520	980	8.03	-	-	-	-	-	-	4.7	200	659	<0.9	-	-	-	-	-	-	-	-	-	-
MW-8	5/6/2013	BCL	1490	950	8.0	-	-	-	-	-	-	<2	200	520	<0.9	-	-	-	-	-	-	-	-	-	-
MW-8	10/24/2013	BCL	1520	880	8.1	-	-	-	-	-	-	2	220	490	<0.9	-	-	-	-	-	-	-	-	-	-
MW-8	5/16/2014	BCL	1580	930	8.2	-	-	-	-	-	-	4	230	480	<0.9	-	-	-	-	-	-	-	-	-	-
MW-8	10/16/2014	BCL	1550	820	8.1	-	-	-	-	-	-	7	220	470	ND	-	-	-	-	-	-	-	-	-	-
MW-10	4/7/1984	UNK	750	427	7.6	-	-	14.1	3.1	150	1.6	17	75	300	-	-	-	0.02	-	-	0.07	0.13	-	-	-
MW-10	7/19/1984	UNK	770	460	7.6	-	-	14.7	3.5	159	2.5	17	79.6	319	-	-	-	-	-	-	0.22	0.16	-	-	-
MW-10	11/28/1984	UNK	690	417	7.9	-	-	11	2.2	147	1.3	14	68	294	-	-	-	0.06	-	-	0.08	0.11	-	-	-
MW-10	4/24/1985	UNK	720	453	8.0	-	-	12	2.3	156	1.2	16	70.8	321	-	-	-	-	-	-	-	0.15	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations					Anions				Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
DEEP (Spreckels)																									
MW-10	10/20/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<0.4	-
MW-10	5/20/2010	BCL	1370	860	8.2	490	-	26	3.4	320	2.1	5.6	160	600	<0.4	-	-	-	-	<0.002	0.14	0.17	-	-	<0.005
MW-10	9/15/2010	BCL	-	920	8.22	470	-	24	2.9	310	2	5.3	160	570	-	-	<2	0.13	0.053	<0.002	0.1	0.17	-	-	<0.005
MW-10	9/15/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1.4	<0.4	-
MW-10	4/20/2011	BCL	1260	800	8.21	470	-	20	2.4	290	1.9	4.1	150	570	<0.4	-	-	-	-	<0.002	0.1	0.13	-	-	<0.005
MW-10	9/1/2011	BCL	1340	810	8.19	470	-	20	2.4	300	2.1	3.9	150	570	<0.4	-	<2	0.12	0.054	<0.002	0.11	0.14	-	-	<0.005
MW-10	9/1/2011	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
MW-10	3/29/2012	BCL	1320	900	8.14	460	-	22	2.7	290	1.9	5.6	150	573	<0.4	-	-	-	-	0.0043	0.11	0.15	-	-	<0.005
MW-10	10/4/2012	BCL	1300	800	8.19	480	-	20	2.3	300	1.8	6.4	150	586	<0.9	-	<2	0.1	0.049	<0.002	0.094	0.14	<1	-	<0.005
MW-10	10/4/2012	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
MW-10	5/7/2013	BCL	1290	780	8.31	470	-	22	2.6	300	2	8.9	150	560	<0.4	-	-	-	-	<0.004	0.11	0.16	-	-	<0.01
MW-10	10/23/2013	BCL	1340	840	8.3	-	-	-	-	-	-	6	160	460	<0.4	-	-	-	-	-	-	-	-	-	-
MW-10	5/15/2014	BCL	1530	920	8.3	-	-	-	-	-	-	6	170	490	<0.4	-	-	-	-	-	-	-	-	-	-
MW-10	10/17/2014	BCL	1650	940	8.1	-	-	-	-	-	-	7	210	540	ND	-	-	-	-	-	-	-	-	-	-
MW-11	4/7/1984	UNK	1320	807	8.2	-	-	7.5	0.6	313	1	-	100	630	-	-	-	0.14	-	-	0.07	0.09	-	-	-
MW-11	7/19/1984	UNK	1350	877	8.4	-	-	8.9	1	326	1.1	7	106	643	-	-	-	-	-	-	0.06	0.08	-	-	-
MW-11	11/28/1984	UNK	1320	910	8.2	-	-	9	0.7	329	1.2	-	106	674	-	-	-	0.12	-	-	0.05	0.07	-	-	-
MW-11	4/24/1985	UNK	1360	873	8.2	-	-	9.8	0.8	337	1.1	5	106	653	-	-	-	-	-	-	-	0.06	-	-	-
MW-11	11/5/1985	UNK	1360	935	8.1	-	-	10	0.9	332	1.2	-	108	723	-	-	-	-	-	-	-	0.09	-	-	-
MW-11	9/24/1986	UNK	1360	885	8.2	-	-	11	1.2	333	1.1	10	103	708	-	-	-	-	-	-	-	0.08	-	-	-
MW-11	3/29/1988	UNK	1375	885	8.3	-	-	11	1.2	343	1.3	-	7	687	-	-	-	-	-	-	-	0.01	-	-	-
MW-11	12/1/1988	BCL	1460	940	8.3	-	36.8	6	1	370	1	6	113	797	<0.4	-	-	-	-	-	<0.05	0.02	-	-	-
MW-11	1/13/1989	UNK	1460	940	8.3	-	-	6	0.8	370	1.4	6	113	797	-	-	-	-	-	-	-	-	-	-	-
MW-11	12/14/1989	UNK	1590	1050	8.1	-	-	17	2	380	1.4	15	119	858	-	-	-	-	-	-	0.074	0.13	-	-	-
MW-11	11/14/1990	UNK	-	995	7.6	-	-	-	-	-	1.6	-	112	899	-	-	-	-	-	-	0.106	0.227	-	-	-
MW-11	6/20/1991	UNK	1600	1040	7.9	-	-	-	-	-	1.4	-	131	855	-	-	-	-	-	-	-	-	-	-	-
MW-11	10/29/1991	UNK	1590	1000	8.2	-	-	20	2.6	382	1.4	-	132	844	-	-	-	0.17	-	-	0.07	0.187	-	-	-
MW-11	2/24/1992	UNK	1560	1040	8.0	-	-	25	28	360	1.4	-	119	823	-	-	-	0.22	-	-	0.107	0.239	-	-	-
MW-11	10/20/1992	UNK	1640	1010	7.7	-	-	25	3	360	1.7	-	133	871	-	-	-	0.16	-	-	0.081	0.23	-	-	-
MW-11	3/1/1993	UNK	1660	1010	7.9	-	-	25.4	3.9	382	1.5	-	148	899	-	-	-	0.2	-	-	0.125	0.326	-	-	-
MW-11	9/22/1993	BCL	1650	1040	7.7	-	16.7	31	4	371	1.8	<5	149	-	-	-	-	-	-	-	-	-	-	-	-
MW-11	9/27/1993	UNK	1650	1040	7.7	-	-	31	4	371	1.8	-	149	889	-	-	-	0.19	-	-	0.155	0.448	-	-	-
MW-11	3/10/1994	UNK	1770	1070	7.8	-	-	34	4.8	393	1.8	-	164	872	-	-	-	-	-	-	-	-	-	-	-
MW-11	9/20/1994	UNK	1750	1080	7.7	-	-	43	6.1	373	1.8	-	167	864	-	-	-	0.2	0.11	-	0.12	0.52	-	-	-
MW-11	3/16/1995	UNK	1680	1030	7.6	-	-	40	5.9	374	1.9	-	162	846	-	-	-	0.18	0.107	-	-	0.378	-	-	-
MW-11	10/10/1995	UNK	1700	1100	7.9	-	-	40	5.4	350	1.7	-	163	789	-	-	-	0.19	0.11	-	-	0.48	-	-	-
MW-11	4/6/1996	UNK	1740	1040	7.7	-	-	40	6	366	1.7	-	175	863	-	-	-	0.2	-	-	-	0.122	-	-	-
MW-11	6/10/1996	UNK	1750	1010	8.4	-	-	43	6.5	381	2.5	-	165	876	-	-	-	0.2	0.118	-	-	0.48	-	-	-
MW-11	6/3/1997	UNK	1720	1070	8.3	-	-	39	5.7	380	1.8	-	163	822	-	-	-	0.2	0.114	-	-	0.493	-	-	-
MW-11	3/23/1998	UNK	1400	1000	7.7	-	-	41	5.8	390	5.2	-	170	660	-	-	-	0.21	0.12	-	-	0.37	-	-	-
MW-11	8/26/1998	UNK	1700	1000	8.0	-	-	41	5.4	380	2	ND	170	690	ND	ND	-	0.2	0.12	-	ND	0.41	-	-	-
MW-11	4/20/1999	BSK	1600	1000	7.7	-	15.4	41	6	400	2	<40	180	700	<0.2	-	-	0.2	-	-	<0.05	0.4	-	-	-
MW-11	11/1/1999	BSK	1800	1000	7.8	-	14.7	40	5	370	2	<40	180	620	<0.2	-	-	0.2	-	-	<0.05	0.4	-	-	-
MW-11	5/21/2000	BSK	1600	1100	7.7	700	15	38	4.8	370	2	<40	190	854	<4	<2	-	0.2	0.1	-	0.08	0.39	-	-	-
MW-11	12/19/2000	BSK	1900	1200	7.5	680	14.2	40	5.4	360	<2	<40	220	-	<4	<2	-	0.2	0.11	-	<0.05	0.37	-	-	-
MW-11	6/5/2001	BSK	1700	1100	7.4	680	15.8	41	6.1	410	2	<40	230	830	-	<2	-	0.2	0.11	-	<0.05	0.43	-	-	-
MW-11	10/3/2001	UNK	1900	1400	7.4	-	-	46	7.1	400	ND	ND	220	740	27.9	ND	-	0.2	0.13	-	0.09	0.41	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
DEEP (Spreckels)																									
MW-12	6/20/1991	UNK	4000	2480	7.3	-	-	-	-	-	5.2	-	466	1946	-	-	-	-	0.532	-	-	-	-	-	-
MW-12	10/29/1991	UNK	4200	2540	7.3	-	-	120	38	830	5.8	12	493	1950	-	-	-	0.2	0.648	-	4.58	2.02	-	-	-
MW-12	2/24/1992	UNK	4300	2620	7.2	-	-	130	43	840	8.3	12	496	1990	25.7	-	-	0.22	0.739	-	6.25	2.15	-	-	-
MW-12	10/20/1992	UNK	5400	3440	6.8	-	-	180	41	1010	9.6	-	580	2540	-	-	-	0.2	0.951	-	8.4	2.52	-	-	-
MW-12	3/1/1993	UNK	4800	2910	6.9	-	-	168	50	950	11.4	-	565	2260	-	-	-	0.23	1.01	-	8.47	2.24	-	-	-
MW-12	9/22/1993	BCL	-	1010	8.0	-	10.6	49	11	314	2.9	180	280	-	-	-	-	-	-	-	-	-	-	-	-
MW-12	9/27/1993	UNK	5000	3180	6.9	-	-	167	49	967	13.4	-	605	2330	-	-	-	0.17	1.22	-	10.2	2.55	-	-	-
MW-12	3/10/1994	UNK	4680	3000	7.0	-	-	143	42	973	13.5	-	570	2190	-	0.06	-	0.18	1.15	-	10	2.05	-	-	-
MW-12	9/20/1994	UNK	5190	3250	7.0	-	-	124	51	1020	23	-	665	2330	-	-	-	0.16	1.14	-	2.81	2.15	-	-	-
MW-12	3/16/1995	UNK	4950	3150	6.8	-	-	154	47	1020	20	-	650	2310	-	-	-	0.16	0.942	-	0.331	1.32	-	-	-
MW-12	10/10/1995	UNK	5370	3540	7.0	-	-	170	50	1070	23	-	710	2490	-	-	-	0.24	1.26	-	0.52	1.26	-	-	-
MW-12	4/6/1996	UNK	5500	3240	7.0	-	-	157	57	1040	35	-	745	2490	-	-	-	0.25	1.98	-	10	1.13	-	-	-
MW-12	6/10/1996	UNK	5330	3310	7.9	-	-	145	48	1090	45	-	702	2400	-	-	-	0.24	1.55	-	0.276	1.49	-	-	-
MW-12	6/3/1997	UNK	5290	3240	7.1	-	-	142	45	984	48	-	670	2490	-	-	-	0.26	1.63	-	0.292	1.59	-	-	-
MW-12	3/23/1998	UNK	4500	3200	7.1	-	-	130	43	1000	74	-	680	1900	-	-	-	0.2	2	-	0.24	0.71	-	-	-
MW-12	8/26/1998	UNK	5400	3200	7.3	-	-	160	43	1000	44	ND	720	2000	ND	-	-	0.23	1.6	-	0.32	1.3	-	-	-
MW-12	4/21/1999	BSK	4900	3100	7.3	1900	22.5	140	46	1200	47	<100	670	2318	<10	<5	-	0.3	1.5	-	0.23	0.88	-	-	-
MW-12	5/20/2000	BSK	4700	3000	7.1	2000	21.7	110	29	990	43	<100	740	2440	12	<5	-	0.3	1.2	-	0.23	0.7	-	-	-
MW-12	12/17/2000	BSK	4400	2800	7.1	1600	18.2	99	27	790	35	<100	650	1952	<10	<5	-	0.3	0.99	-	0.16	0.53	-	-	-
MW-12	6/5/2001	BSK	4700	2800	7.4	1600	21.7	100	29	960	40	<100	710	1952	<10	<5	-	0.3	1.1	-	0.2	0.85	-	-	-
MW-12	10/3/2001	UNK	4500	2700	6.9	-	-	110	33	880	31	ND	630	1700	ND	ND	-	0.2	0.89	-	0.15	0.71	-	-	-
MW-12	5/2/2002	BSK	4100	2400	7.5	1500	-	94	25	750	21	<120	600	1500	<12	<6	-	0.2	0.8	-	0.15	0.58	-	-	-
MW-12	12/10/2002	BSK	4300	2600	7.8	560	-	84	21	700	24	-	610	-	-	ND	-	0.2	0.84	-	0.14	0.5	-	-	-
MW-12	3/22/2003	BSK	4300	2700	7.6	1500	-	93	26	750	22	ND	610	-	-	ND	-	0.2	0.79	-	0.18	0.43	-	-	-
MW-12	10/24/2003	BSK	5200	3200	7.6	1900	-	120	37	990	48	ND	710	-	-	ND	-	0.2	1.4	-	0.32	0.71	-	-	-
MW-12	3/31/2004	BSK	5200	3200	7.4	2000	-	120	42	1100	70	<2	790	2440	<0.9	<0.1	-	0.2	1.6	-	0.46	0.69	-	-	-
MW-12	11/13/2004	BSK	5500	3400	7.7	2100	-	120	44	1100	91	<40	790	2560	<18	<2	-	0.3	1.8	-	0.23	0.62	-	-	-
MW-12	4/6/2005	UNK	5400	3300	7.7	2100	-	100	37	1100	79	ND	810	2100	ND	ND	-	0.3	1.6	-	0.27	0.63	-	-	-
MW-12	10/13/2005	UNK	5600	3300	7.9	2000	-	98	39	1100	87	ND	820	2000	ND	ND	-	0.3	1.7	-	0.3	0.73	-	-	-
MW-12	4/19/2006	DL	5625	3115	7.4	1895	-	79	54	891	112	0.4	674	1895	<0.1	<0.1	-	0.16	1.27	-	0.28	0.58	-	-	-
MW-12	9/25/2006	UNK	4750	2470	7.2	1677	-	57.8	23.4	668	88.5	ND	649	1677	ND	ND	-	0.21	0.85	-	0.17	0.54	-	-	-
MW-12	3/29/2007	TL	3300	1900	7.3	1200	-	36	12	580	110	<20	370	1400	<20	<1	<10	0.23	0.86	<0.005	-	-	<5	-	0.0056
MW-12	9/23/2007	TL	3100	1700	7.2	-	-	-	-	-	-	<20	400	1400	<20	-	-	-	-	-	-	-	-	-	-
MW-12	4/5/2008	BCL	3250	1900	7.62	-	-	-	-	-	-	<2	420	1464	<0.9	-	-	-	-	-	-	-	-	-	-
MW-12	9/3/2008	BCL	3530	2100	7.4	-	-	-	-	-	-	<2	550	1464	<0.4	-	-	-	0.46	-	-	-	-	-	-
MW-12	4/2/2009	BCL	3400	2100	7.6	-	-	-	-	-	-	ND	540	1200	ND	-	-	-	0.5	-	-	-	-	-	-
MW-12	10/1/2009	BSK	3000	1700	8.0	-	-	-	-	-	-	<20	450	1220	<10	-	-	-	-	-	-	-	-	-	-
MW-12	5/4/2011	SSC	5300	3100	7.1	-	-	-	-	-	-	<10	750	1800	<2.2	-	-	-	-	-	-	-	-	-	-
MW-12	9/12/2011	SSC	5200	3100	7.0	-	-	-	-	-	-	<10	740	1800	<2.2	-	-	-	-	-	-	-	-	-	-
MW-12	3/30/2012	BCL	4350	2700	7.64	-	-	-	-	-	-	2	620	1830	<2.2	-	-	-	-	-	-	-	-	-	-
MW-12	10/4/2012	BCL	3450	2200	7.52	-	-	-	-	-	-	18	470	1586	<2.2	-	-	-	-	-	-	-	-	-	-
MW-12	5/6/2013	BCL	2780	1900	7.5	-	-	-	-	-	-	15	360	1100	<0.9	-	-	-	-	-	-	-	-	-	-
MW-12	10/24/2013	BCL	3170	2000	7.6	-	-	-	-	-	-	7	430	1100	<2.2	-	-	-	-	-	-	-	-	-	-
MW-12	5/16/2014	BCL	2300	1300	7.9	-	-	-	-	-	-	21	300	760	<0.9	-	-	-	-	-	-	-	-	-	-
MW-12	10/16/2014	BCL	1940	1100	7.8	-	-	-	-	-	-	26	230	630	ND	-	-	-	-	-	-	-	-	-	-
MW-14	3/31/1984	UNK	1220	707	8.3	-	-	6	0.6	265	1.3	140	140	244	-	-	-	0.1	-	-	-	0.04	-	-	-
MW-14	11/29/1984	UNK	1400	887	8.1	-	-	26	4.2	287	2.2	195	189	305	-	-	-	0.12	-	-	0.06	0.08	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
DEEP (Spreckels)																									
MW-14	4/19/2006	UNK	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW-14	9/26/2006	TL	1014	633	8.1	-	-	-	-	-	-	114	128	259	ND	-	-	-	-	-	-	-	-	-	-
MW-14	9/26/2006	UNK	-	-	-	259	-	41.8	9	185	3	-	-	-	-	ND	-	0.29	0.06	-	ND	0.33	-	-	-
MW-14	3/29/2007	TL	1000	640	7.8	260	-	41	9.7	180	5.6	96	120	310	<6	<0.3	<10	0.29	0.075	<0.005	-	-	6.7	-	<0.005
MW-14	3/29/2007	UNK	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW-14	9/24/2007	BCL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW-14	9/24/2007	TL	1000	630	7.7	280	-	45	9.7	180	5.4	100	110	340	ND	-	ND	0.28	0.084	ND	0.11	0.33	-	-	ND
MW-14	4/6/2008	BCL	1100	670	8.12	-	-	-	-	-	-	110	120	378	<0.4	-	-	-	-	-	-	-	-	-	-
MW-14	9/3/2008	BCL	1100	640	8.1	-	-	-	-	-	-	100	120	378	<0.4	-	-	-	0.058	-	-	-	-	-	-
MW-14	10/2/2009	BSK	1000	630	8.3	-	-	-	-	-	-	95	110	354	<2	-	-	-	-	-	-	-	-	-	-
MW-14	10/6/2010	SSC	1200	720	7.7	-	-	-	-	-	-	93	120	403	<2	-	-	-	-	-	-	-	-	-	-
MW-14	5/19/2011	SSC	1200	690	7.6	-	-	-	-	-	-	98	120	330	<2.2	-	-	-	-	-	-	-	-	-	-
MW-14	9/21/2011	SSC	1100	650	7.8	-	-	-	-	-	-	95	110	310	<2.2	-	-	-	-	-	-	-	-	-	-
MW-14	3/30/2012	BCL	1170	700	8.19	-	-	-	-	-	-	100	120	366	<0.4	-	-	-	-	-	-	-	-	-	-
MW-14	10/4/2012	BCL	1110	750	8.15	-	-	-	-	-	-	100	120	366	<0.4	-	-	-	-	-	-	-	-	-	-
MW-14	5/7/2013	BCL	1130	740	8.1	-	-	-	-	-	-	110	130	310	<0.4	-	-	-	-	-	-	-	-	-	-
MW-14	10/23/2013	BCL	1080	690	8.1	-	-	-	-	-	-	93	120	290	<0.4	-	-	-	-	-	-	-	-	-	-
MW-14	5/15/2014	BCL	1180	710	8.1	-	-	-	-	-	-	99	120	300	<0.4	-	-	-	-	-	-	-	-	-	-
MW-14	10/17/2014	BCL	1160	660	8.0	-	-	-	-	-	-	100	120	310	ND	-	-	-	-	-	-	-	-	-	-
MW-16	12/8/1988	BCL	11600	6100	7.4	-	37.2	54	38	1460	1172	38	1094	5752	1	0.1	<10	0.2	3.7	-	0.33	0.18	-	<5	-
MW-16	12/20/1988	UNK	-	2190	7.4	-	-	30	30	200	120	25	389	1803	-	-	-	-	-	-	0.05	0.04	-	-	-
MW-16	12/19/1989	UNK	10400	6800	7.6	-	-	76	65	1360	696	125	1055	4936	-	-	-	-	-	-	0.577	0.358	-	-	-
MW-16	4/10/1990	UNK	9500	5260	7.3	-	-	63	54	1250	760	70	1063	4418	-	-	-	-	-	-	0.665	0.24	-	-	-
MW-16	11/16/1990	UNK	-	5060	7.1	-	-	-	-	-	690	-	922	4401	-	-	-	-	3.38	-	1.16	0.248	-	-	-
MW-16	6/18/1991	UNK	8400	4650	7.2	-	-	-	-	-	445	-	893	4007	-	-	-	-	3.74	-	-	-	-	-	-
MW-16	10/22/1991	UNK	8000	4360	7.1	-	-	77	49	1170	540	22	847	3790	-	-	-	0.28	3.12	-	8.62	0.3	-	-	-
MW-16	2/25/1992	UNK	8200	4340	7.5	-	-	79	56	1140	590	28	823	3940	-	-	-	0.26	3	-	7.6	0.221	-	-	-
MW-16	10/22/1992	UNK	-	2240	7.1	-	-	44	27	595	275	-	497	1510	-	-	-	0.3	2.64	-	8.31	0.282	-	-	-
MW-16	3/8/1993	UNK	7000	3420	7.3	-	-	62	40	955	500	-	620	3320	-	-	-	0.36	2.32	-	4.93	0.197	-	-	-
MW-16	9/23/1993	UNK	6200	3250	7.4	-	-	50	34	857	443	-	570	2980	-	-	-	0.31	2.27	-	5.59	0.197	-	-	-
MW-16	3/14/1994	UNK	5660	3020	7.3	-	-	49	31	830	410	6	520	2720	-	-	-	0.35	1.93	-	4.33	0.194	-	-	-
MW-16	10/3/1994	UNK	5200	2800	7.2	-	-	55	28	795	74	24	505	2460	-	-	-	0.3	1.81	-	5.23	0.21	-	-	-
MW-16	3/20/1995	UNK	4910	2900	7.1	-	-	35	23	746	316	34	474	2310	-	-	-	0.3	1.26	-	0.308	0.162	-	-	-
MW-16	10/14/1995	UNK	4880	2560	7.3	-	-	33	22	683	314	28	457	2280	-	-	-	0.36	1.24	-	0.25	0.135	-	-	-
MW-16	4/8/1996	UNK	4900	2710	8.6	-	-	33	24	720	328	24	447	2410	-	-	-	0.38	1.2	-	0.373	0.13	-	-	-
MW-16	10/4/1996	UNK	4810	2400	8.6	-	-	30	21	688	309	25.6	395	2310	-	-	-	0.38	1.24	-	0.177	0.121	-	-	-
MW-16	6/6/1997	UNK	4640	2440	7.4	-	-	32	23	711	318	14.9	413	2550	-	-	-	0.4	1.42	-	0.244	0.126	-	-	-
MW-16	4/21/1999	BSK	7000	3700	7.7	2900	26.3	49	37	1000	590	<150	630	3538	<15	<7.5	-	0.3	2.6	-	0.59	0.16	-	-	-
MW-16	5/21/2000	BSK	6800	3900	7.3	1500	28.1	43	31	990	500	<150	680	1830	<15	<7.5	-	0.3	2.5	-	0.62	0.16	-	-	-
MW-16	12/17/2000	BSK	6400	3500	7.4	2900	21.5	42	29	740	440	<140	620	3538	<14	<7	-	0.3	2.2	-	0.82	0.16	-	-	-
MW-16	6/6/2001	BSK	6200	3400	7.2	2500	23	44	32	820	510	<80	650	3050	-	<4	-	0.4	2.2	-	0.44	0.16	-	-	-
MW-16	10/3/2001	UNK	6000	3000	7.2	-	-	42	30	780	440	ND	520	2600	ND	ND	-	0.3	1.7	-	0.42	0.13	-	-	-
MW-16	5/2/2002	BSK	6000	3000	7.6	2400	-	30	22	640	330	<20	58	2400	2.5	<1	-	0.3	1.6	-	0.34	0.11	-	-	-
MW-16	12/10/2002	BSK	5600	2800	7.4	2200	-	25	17	610	300	ND	480	-	-	ND	-	0.3	1.5	-	0.38	0.12	-	-	-
MW-16	3/22/2003	BSK	5600	3000	7.6	2200	-	33	24	690	320	ND	560	-	-	ND	-	0.3	1.6	-	0.52	0.14	-	-	-
MW-16	10/25/2003	BSK	5400	2800	7.8	2300	-	36	27	720	420	ND	430	-	-	ND	-	0.3	1.5	-	0.43	0.13	-	-	-
MW-16	4/1/2004	UNK	6300	3300	7.7	2700	-	41	34	780	450	ND	580	2700	ND	ND	-	0.3	1.9	-	0.58	0.15	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
DEEP (Spreckels)																									
MW-22	10/25/2003	BSK	1800	-	8.2	480	-	11	2.2	330	12	74	230	-	-	ND	-	0.1	0.1	-	0.56	0.16	-	-	-
MW-22	4/1/2004	UNK	1800	1100	8.0	510	-	14	2.8	410	15	75	250	510	ND	ND	-	0.2	0.15	-	0.7	0.2	-	-	-
MW-22	11/14/2004	BSK	1700	1000	8.2	500	-	13	2.5	350	11	82	230	610	<4	<0.5	-	0.1	0.11	-	0.56	0.17	-	-	-
MW-22	4/7/2005	UNK	1800	1000	7.9	520	-	16	2.7	380	11	84	250	520	ND	ND	-	0.1	0.14	-	0.57	0.19	-	-	-
MW-22	10/14/2005	UNK	1800	1000	8.4	500	-	14	2.3	420	10	86	230	480	ND	ND	-	0.1	0.13	-	0.49	0.18	-	-	-
MW-22	4/19/2006	DL	1866	1178	7.8	578	-	16	2.7	376	22	74	249	578	<0.1	<0.1	-	0.09	0.15	-	0.23	0.19	-	-	-
MW-22	9/25/2006	UNK	1719	1187	7.9	605	-	15.1	2.7	402	15.5	88	288	605	ND	ND	-	0.11	0.13	-	0.19	0.19	-	-	-
MW-22	3/29/2007	TL	2000	1200	7.6	600	-	19	3.1	440	25	68	250	740	<10.2	<0.5	<10	0.15	0.18	<0.005	-	-	8.9	-	<0.005
MW-22	9/23/2007	TL	2300	1300	7.5	-	-	-	-	-	-	62	280	890	<20	-	-	-	-	-	-	-	-	-	-
MW-22	4/5/2008	BCL	2490	1500	7.8	-	-	-	-	-	-	53	310	1013	<0.9	-	-	-	-	-	-	-	-	-	-
MW-22	9/3/2008	BCL	2710	1700	7.6	-	-	-	-	-	-	42	380	1122	<0.4	-	-	-	0.27	-	-	-	-	-	-
MW-22	4/2/2009	UNK	2800	1700	7.7	-	-	-	-	-	-	34	390	970	ND	-	-	-	0.3	-	-	-	-	-	-
MW-22	10/1/2009	BSK	3000	1600	8.0	-	-	-	-	-	-	24	390	1342	<10	-	-	-	-	-	-	-	-	-	-
MW-22	10/19/2010	SSC	3100	1900	7.2	-	-	-	-	-	-	14	400	1400	<2	-	-	-	-	-	-	-	-	-	-
MW-22	6/2/2011	SSC	3100	1900	7.3	-	-	-	-	-	-	24	400	1100	<2.2	-	-	-	-	-	-	-	-	-	-
MW-22	10/3/2011	SSC	3200	2000	7.2	-	-	-	-	-	-	20	410	1200	<2.2	-	-	-	-	-	-	-	-	-	-
MW-22	3/30/2012	BCL	3230	2100	7.79	-	-	-	-	-	-	16	420	1342	<2.2	-	-	-	-	-	-	-	-	-	-
MW-22	10/4/2012	BCL	2990	1800	7.67	-	-	-	-	-	-	25	390	1342	<2.2	-	-	-	-	-	-	-	-	-	-
MW-22	5/6/2013	BCL	3020	2100	7.5	-	-	-	-	-	-	21	410	1100	<2.2	-	-	-	-	-	-	-	-	-	-
MW-22	10/24/2013	BCL	3160	2000	7.6	-	-	-	-	-	-	16	420	1200	<2.2	-	-	-	-	-	-	-	-	-	-
MW-22	5/16/2014	BCL	3370	2000	8.2	-	-	-	-	-	-	14	430	1200	<2.2	-	-	-	-	-	-	-	-	-	-
MW-22	10/17/2014	BCL	3490	2000	7.4	-	-	-	-	-	-	9	450	1300	ND	-	-	-	-	-	-	-	-	-	-
PW-1	3/24/1962	UNK	-	235	-	-	-	-	-	-	-	-	60	-	-	-	-	-	-	-	-	-	-	-	-
PW-1	10/24/1963	TL	-	114	8.8	-	-	1	<1	37	-	3	14	58	-	-	-	<0.1	-	-	-	-	-	-	-
PW-1	12/14/1964	UNK	-	169	8.2	-	-	2.5	0.5	51	-	3.3	24.8	97.6	-	-	-	0.05	-	-	2	-	-	-	-
PW-1	5/17/1965	UNK	-	149	8.3	-	-	2.6	-	48	-	6.2	17.7	85.4	-	-	-	-	-	-	2.8	-	-	-	-
PW-1	3/1/1966	UNK	-	177	8.8	-	-	4.9	-	50	-	4.9	28.4	79.3	-	-	-	-	-	-	4	-	-	-	-
PW-1	11/12/1968	UNK	-	169	-	-	-	1.4	0.9	92	1	-	30	96	-	-	-	-	-	-	-	-	-	-	-
PW-1	7/19/1980	UNK	-	284	8.3	-	-	17	3	-	-	14	-	74	-	-	-	-	-	-	0.1	-	-	-	-
PW-1	11/4/1980	UNK	-	300	8.2	-	-	11	3	-	-	11	-	76	-	-	-	-	-	-	0.1	-	-	-	-
PW-1	12/13/1980	UNK	-	235	8.7	-	-	12	-	-	-	8	-	72	-	-	-	-	-	-	0.1	-	-	-	-
PW-1	5/16/1981	UNK	-	236	8.5	-	-	6	2	-	-	27	-	83	-	-	-	-	-	-	ND	-	-	-	-
PW-1	8/6/1981	UNK	-	256	8.8	-	-	6	2	-	-	29	-	55	-	-	-	-	-	-	ND	-	-	-	-
PW-1	10/3/1981	UNK	-	232	8.7	-	-	6	2	-	-	27	-	61	-	-	-	-	-	-	ND	-	-	-	-
PW-1	11/10/1981	UNK	473	294	8.6	-	-	6	1	93	1	32	57	157	1.3	-	-	0.1	-	-	0.4	0.04	-	-	-
PW-1	2/2/1982	UNK	-	288	8.7	-	-	7	1	-	-	26	-	67	-	-	-	-	-	-	0.1	-	-	-	-
PW-1	5/15/1982	UNK	-	260	8.6	-	-	6	4	-	-	25	-	63	-	-	-	-	-	-	ND	-	-	-	-
PW-1	10/8/1982	UNK	-	240	8.2	-	-	28	3	-	-	29	-	74	-	-	-	-	-	-	0.1	-	-	-	-
PW-1	11/24/1982	UNK	460	280	8.6	-	-	3	0.37	96	1.2	22	47.4	147.3	-	0.18	-	0.11	-	-	0.05	0.02	-	-	-
PW-1	5/6/1983	UNK	-	168	8.5	-	-	4	ND	-	-	38	-	96	-	-	-	-	-	-	-	-	-	-	-
PW-1	5/10/1983	BCL	430	223	8.5	-	-	3	<1	98	1	26	44	135	<1	-	<10	-	-	-	0.08	0.02	-	-	-
PW-1	12/2/1983	UNK	470	283	8.0	-	-	5.4	0.86	100	1.4	24	53.1	166	-	-	-	-	-	-	0.52	0.04	-	-	-
PW-1	3/2/1984	UNK	510	290	8.2	-	-	4.4	0.66	105	0.7	22	56.6	149	-	-	-	-	-	-	-	0.02	-	-	-
PW-1	5/22/1984	UNK	500	280	8.2	-	-	6.7	1	95	1	23	49.2	140	-	-	-	-	-	-	0.07	0.04	-	-	-
PW-1	6/19/1984	UNK	-	240	7.9	-	-	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PW-1	7/17/1984	UNK	480	303	8.6	-	-	3.9	0.76	101	0.7	22	53.1	136	-	-	-	-	-	-	0.06	0.02	-	-	-
PW-1	11/27/1984	UNK	510	327	8.1	-	-	22	4.1	84	2	26	62.3	172	-	-	-	0.2	-	-	0.35	0.18	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Cations				Anions					Trace Elements								
								Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
DEEP (Spreckels)																									
PW-2	11/10/1983	UNK	-	1256	6.9	-	-	70	8	-	-	8	-	449	-	-	-	-	-	-	1.9	-	-	-	-
PW-2	11/18/1983	UNK	2200	1273	7.7	-	-	59	12	425	4.3	28	270	838	4	-	-	-	-	-	1.8	0.96	-	-	-
PW-2	1/21/1984	UNK	-	1248	6.2	-	-	72	16	-	-	-	-	442	-	-	-	-	-	-	0.6	-	-	-	-
PW-2	1/23/1984	UNK	-	1148	7.0	-	-	68	12	-	-	-	-	460	-	-	-	-	-	-	2	-	-	-	-
PW-2	2/16/1984	UNK	-	956	7.3	-	-	53	9	-	-	-	-	348	-	-	-	-	-	-	2	-	-	-	-
PW-2	2/18/1984	UNK	-	1520	7.3	-	-	40	9	-	-	-	-	318	-	-	-	-	-	-	1	-	-	-	-
PW-2	2/22/1984	UNK	-	920	7.4	-	-	36	7	-	-	-	-	268	-	-	-	-	-	-	1	-	-	-	-
PW-2	2/29/1984	UNK	-	824	7.3	-	-	33	6	-	-	-	-	268	-	-	-	-	-	-	1	-	-	-	-
PW-2	3/7/1984	UNK	-	700	7.2	-	-	30	10	-	-	-	-	279	-	-	-	-	-	-	1	-	-	-	-
PW-2	3/14/1984	UNK	-	688	7.0	-	-	28	6	-	-	-	-	281	-	-	-	-	-	-	1	-	-	-	-
PW-2	3/20/1984	UNK	690	370	7.8	-	-	46	8.9	84	3.2	75	743	201	-	-	-	-	-	-	0.16	0.04	-	-	-
PW-2	3/29/1984	UNK	-	692	6.9	-	-	27	8	-	-	29	-	275	-	-	-	-	-	-	0.8	-	-	-	-
PW-2	7/17/1984	UNK	1300	827	7.5	-	-	11	4.5	275	2	26	168	467	-	-	-	-	-	-	1.3	0.51	-	-	-
PW-2	11/27/1984	UNK	880	560	7.5	-	-	42	8.3	144	3.4	48	118	291	-	-	-	0.08	-	-	0.62	0.46	-	-	-
PW-2	4/29/1985	UNK	1800	1100	8.2	-	-	62	12	334	4.4	27	243	614	-	-	-	-	-	-	-	-	-	-	-
PW-2	11/6/1985	UNK	810	500	8.3	-	-	36	6.7	135	2.6	45	105	252	-	-	-	-	-	-	-	-	-	-	-
PW-2	9/23/1986	UNK	910	555	7.9	-	-	74	14.1	105	4.1	93	108	285	-	-	-	-	-	-	-	-	-	-	-
PW-2	9/3/1987	UNK	2200	1280	7.5	-	-	58	9.7	425	4	30	277	858	-	-	-	-	0.26	-	0.05	0.99	-	-	-
PW-2	3/29/1988	UNK	2600	1605	7.1	-	-	74	14	476	13	25	330	956	-	-	-	-	0.4	-	-	1.3	-	-	-
PW-3	10/24/1963	TL	-	138	8.7	-	-	1	<1	41	-	4	14	67	-	-	-	<0.1	-	-	-	-	-	-	-
PW-3	3/1/1966	UNK	-	293	8.6	-	-	3.3	-	98	-	37	67.4	94.5	-	-	-	-	-	-	-	-	-	-	-
PW-3	11/12/1968	UNK	-	143	-	-	-	3.6	1.7	80	-	-	16	93	-	-	-	-	-	-	-	-	-	-	-
PW-3	5/28/1980	UNK	-	576	7.7	-	-	14	2	-	-	6	-	165	-	-	-	-	-	-	-	-	-	-	-
PW-3	7/19/1980	UNK	-	456	7.6	-	-	13	1	-	-	15	-	161	-	-	-	-	-	-	0.2	-	-	-	-
PW-3	11/4/1980	UNK	-	340	8.1	-	-	9	ND	-	-	19	-	98	-	-	-	-	-	-	-	-	-	-	-
PW-3	12/13/1980	UNK	-	396	8.5	-	-	7	ND	-	-	14	-	123	-	-	-	-	-	-	-	-	-	-	-
PW-3	5/16/1981	UNK	-	372	8.5	-	-	7	ND	-	-	9	-	118	-	-	-	-	-	-	0.1	-	-	-	-
PW-3	8/6/1981	UNK	-	432	8.8	-	-	6	2	-	-	9	-	118	-	-	-	-	-	-	0.1	-	-	-	-
PW-3	10/3/1981	UNK	-	560	7.4	-	-	20	2	-	-	12	-	205	-	-	-	-	-	-	0.4	-	-	-	-
PW-3	11/10/1981	UNK	1003	617	7.6	-	-	15	4	200	-	12	134	369	0.9	-	-	0.2	-	-	0.51	0.21	-	-	-
PW-3	2/2/1982	UNK	-	-	7.9	-	-	17	3	-	-	26	-	120	-	-	-	-	-	-	0.4	-	-	-	-
PW-3	5/15/1982	UNK	-	536	7.5	-	-	42	12	-	-	36	-	170	-	-	-	-	-	-	1	-	-	-	-
PW-3	10/8/1982	UNK	-	596	7.9	-	-	14	12	-	-	27	-	174	-	-	-	-	-	-	0.2	-	-	-	-
PW-3	11/22/1982	UNK	800	420	7.7	-	-	36	6	132	4	42	106.2	258.1	-	0.6	-	0.09	-	-	1.3	0.33	-	-	-
PW-3	5/10/1983	BCL	900	590	8.4	-	-	20	6	186	3	32	131	312	<1	-	<10	-	-	-	1.3	0.28	-	-	-
PW-3	11/28/1983	UNK	920	553	7.6	-	-	36	7.9	156	3.4	43	124	296	-	-	-	-	-	-	0.64	0.34	-	-	-
PW-3	3/20/1984	UNK	770	463	7.8	-	-	36	5.4	127	2.4	54	93.1	241	-	-	-	-	-	-	0.36	0.26	-	-	-
PW-3	7/20/1984	UNK	730	447	8.0	-	-	33	5.5	116	2.5	46	88.2	220	-	-	-	-	-	-	0.34	0.25	-	-	-
PW-3	11/28/1984	UNK	710	457	7.6	-	-	36	5.9	112	2.7	45	86	232	-	-	-	0.02	-	-	0.39	0.2	-	-	-
PW-3	4/23/1985	UNK	710	427	8.3	-	-	32	5.5	115	3	47	83.2	210	-	-	-	-	-	-	-	-	-	-	-
PW-3	11/6/1985	UNK	660	405	8.3	-	-	31	4.6	107	2.5	44	76.8	210	-	-	-	-	-	-	-	-	-	-	-
PW-3	9/25/1986	UNK	-	-	-	-	-	32	4.9	105	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PW-3	3/29/1988	UNK	670	415	7.9	-	-	31	4.5	114	2.4	49	77.5	235	-	-	-	-	-	-	0.37	0.2	-	-	-
PW-4	10/24/1963	TL	-	382	8.4	-	-	5	1	117	-	44	99	95	-	-	-	0.2	-	-	-	-	-	-	-
PW-4	3/1/1966	UNK	-	368	8.5	-	-	3.3	-	127	-	52.7	102.8	97.6	-	-	-	-	-	-	-	-	-	-	-
PW-4	11/12/1968	UNK	-	434	-	-	-	4.3	0.9	193	-	-	130	104	-	-	-	-	-	-	-	-	-	-	-
PW-4	5/28/1980	UNK	-	1148	8.2	-	-	17	2	-	-	130	-	434	-	-	-	-	-	-	0.1	-	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
DEEP (Spreckels)																									
PW-5	8/6/1981	UNK	-	984	7.3	-	-	28	3	-	-	-	-	331	-	-	-	-	-	-	-	-	-	-	-
PW-5	11/2/1981	UNK	-	1092	-	-	-	21	8	360	-	17	261	681	3.5	-	-	0.2	-	-	-	-	-	-	-
PW-5	11/10/1981	BCL	7120	3999	7.6	-	-	119	67	1050	220	9	977	3000	10	-	<10	-	-	-	9.93	1.22	-	-	-
PW-5	8/2/1982	UNK	-	-	-	-	-	137	59	1260	400	17	970	-	15.5	-	-	0.2	-	-	0.71	1.4	-	-	-
PW-5	11/24/1982	UNK	7800	4177	7.2	-	-	130	82	1240	350	20	998	3435	-	1.2	-	1.1	-	-	3.5	1.1	-	-	-
PW-5	4/28/1983	BCL	4200	2643	8.0	-	-	29	34	840	150	27	595	1705	<1	-	<10	-	-	-	7.5	0.8	-	-	-
PW-5	10/7/1983	UNK	7200	4433	6.9	-	-	170	82	1300	220	26	995	3283	5.8	-	-	-	-	-	0.51	1.4	-	-	-
PW-5	12/2/1983	UNK	7500	-	-	-	-	-	-	1250	-	-	1032	-	-	-	-	-	-	-	0.65	1.2	-	-	-
PW-5	12/16/1983	UNK	-	2304	7.1	-	-	114	4	-	-	7	-	767	-	-	-	-	-	-	13	-	-	-	-
PW-5	2/15/1984	UNK	-	1544	7.1	-	-	44	21	-	-	ND	-	470	-	-	-	-	-	-	4	-	-	-	-
PW-5	2/29/1984	UNK	-	1488	7.2	-	-	46	10	-	-	6	-	268	-	-	-	-	-	-	3	-	-	-	-
PW-5	3/6/1984	UNK	2800	1513	7.3	-	-	36	12.4	518	37	17	354	960	-	-	-	-	-	-	3.2	0.3	-	-	-
PW-5	3/14/1984	UNK	-	1400	6.7	-	-	38	10	-	-	-	-	503	-	-	-	-	-	-	3	-	-	-	-
PW-5	3/20/1984	UNK	580	327	8.3	-	-	1.9	0.18	124	0.7	18	82.1	149	-	-	-	-	-	-	0.34	0.01	-	-	-
PW-5	3/29/1984	UNK	-	1304	6.9	-	-	37	13	-	-	-	-	495	-	-	-	-	-	-	2.5	-	-	-	-
PW-5	7/17/1984	UNK	2400	1310	7.4	-	-	26	9.1	444	46	11	340	793	-	-	-	-	-	-	2.1	0.24	-	-	-
PW-5	11/27/1984	UNK	2500	1500	7.3	-	-	26	9.3	430	58	13	317	895	-	-	-	0.29	-	-	1.6	0.2	-	-	-
PW-5	4/22/1985	UNK	2500	1503	8.4	-	-	25	8.9	435	55	13	309	811	-	-	-	-	-	-	-	-	-	-	-
PW-5	11/6/1985	UNK	2550	1570	8.4	-	-	26	8.5	490	58	11	323	902	-	-	-	-	-	-	-	-	-	-	-
PW-5	9/23/1986	UNK	710	430	8.2	-	-	3	0.34	160	1	26	105	197	-	-	-	-	-	-	-	-	-	-	-
PW-5	4/22/1987	UNK	3400	1800	7.7	-	-	32	14	530	135	13	385	1361	1.8	-	-	-	-	-	1.1	0.22	-	-	-
PW-5	9/3/1987	UNK	610	375	8.2	-	-	2	0.34	135	0.8	19	88.2	160	-	-	-	-	-	-	0.06	0.08	-	-	-
PW-5	4/29/1988	UNK	390	257	8.5	-	-	1.1	0.5	93	-	10	44.6	147	-	-	-	-	-	-	0.09	0.02	-	-	-
PW-6	4/29/1983	UNK	450	310	8.3	-	-	2.6	0.16	106	1.3	28	49.9	158	-	-	-	-	-	-	0.06	0.02	-	-	-
PW-6	4/30/1983	BCL	390	300	8.3	-	-	2	-	107	1	27	46	158	<1	-	<10	-	-	-	0.05	0.02	-	-	-
PW-6	5/6/1983	UNK	-	168	8.5	-	-	4	ND	-	-	38	-	59	-	-	-	-	-	-	-	-	-	-	-
PW-6	12/3/1983	UNK	450	256	8.3	-	-	2	2	96	-	13	47.1	65	-	-	-	-	-	-	0.32	0.01	-	-	-
PW-6	3/20/1984	UNK	520	310	8.3	-	-	0.9	0.06	111	0.05	25	54.9	149	-	-	-	-	-	-	-	-	-	-	-
PW-6	5/22/1984	UNK	510	333	8.3	-	-	1.5	0.8	114	0.7	24	57.4	158	1.8	-	-	-	-	-	0.08	0.01	-	-	-
PW-6	6/19/1984	UNK	-	344	8.7	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PW-6	7/17/1984	UNK	540	337	8.6	-	-	1.4	0.14	118	0.6	26	57	170	-	-	-	-	-	-	-	-	-	-	-
PW-6	11/28/1984	UNK	540	367	8.4	-	-	1.1	0.14	122	0.7	26	55.2	158	-	-	-	0.16	-	-	0.07	-	-	-	-
PW-6	4/29/1985	UNK	530	333	8.3	-	-	1.5	0.12	120	0.7	26	52.8	184	-	-	-	-	-	-	-	-	-	-	-
PW-6	11/6/1985	UNK	500	320	8.4	-	-	1.2	0.12	111	0.7	-	61.6	165	-	-	-	-	-	-	-	-	-	-	-
PW-6	9/24/1986	UNK	550	385	8.2	-	-	1.9	0.23	129	0.7	39	52.8	194	-	-	-	-	-	-	-	-	-	-	-
PW-6	9/3/1987	UNK	560	355	8.2	-	-	1.6	0.18	126	1.4	27	62	175	-	-	-	-	-	-	-	0.02	-	-	-
PW-6	3/28/1988	UNK	570	375	8.4	-	-	1.8	0.21	130	0.7	30	65.5	173	-	-	-	-	-	-	-	0.02	-	-	-
PW-6	12/13/1988	BCL	800	495	8.3	-	24	3	<1	184	1	28	86	300	<1	-	-	-	<0.1	-	0.07	0.02	-	-	-
PW-6	12/6/1989	UNK	870	570	8.2	-	-	6.8	0.87	187	1	25	92.4	312	-	-	-	-	-	-	0.144	0.136	-	-	-
PW-6	11/9/1990	UNK	-	605	7.9	-	-	-	-	-	1.4	-	117	379	-	-	-	0.16	-	-	0.259	0.191	-	-	-
PW-6	7/9/1991	UNK	960	605	8.1	-	-	-	-	-	1.3	-	110	368	-	-	-	-	-	-	-	-	-	-	-
PW-6	10/29/1991	UNK	1110	680	8.1	-	-	10	1.4	248	1.4	20	137	449	-	0.1	-	0.14	-	-	0.235	0.208	-	-	-
PW-6	10/30/1991	UNK	1110	680	8.1	-	-	10	1.4	248	1.4	20	137	449	-	0.1	-	0.14	-	-	0.235	0.208	-	-	-
PW-6	4/28/1992	UNK	1130	740	8.0	-	-	11.7	-	-	1.4	-	131	465	-	-	-	-	-	-	-	-	-	-	-
PW-6	10/28/1992	UNK	1170	690	7.8	-	-	13.3	1.7	258	1.6	21	132	471	-	0.09	-	0.15	0.1	-	0.31	0.254	-	-	-
PW-6	3/10/1993	UNK	1190	720	7.9	-	-	-	-	-	1.7	-	131	489	-	-	-	-	-	-	-	-	-	-	-
PW-6	9/29/1993	UNK	1260	760	7.7	-	-	14.6	2.1	279	1.7	26	146	487	-	0.1	-	0.14	-	-	0.409	0.288	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
DEEP (Spreckels)																									
PW-7	9/24/1986	UNK	460	345	8.2	-	-	0.9	0.09	108	0.5	35	45.3	153	-	-	-	-	-	-	-	-	-	-	-
PW-7	9/3/1987	UNK	490	340	8.3	-	-	0.7	0.07	113	0.5	19	61.6	142	-	-	-	-	-	-	-	-	-	-	-
PW-7	3/28/1988	UNK	500	315	8.4	-	-	0.8	0.08	111	0.7	19	63	137	-	-	-	-	-	-	-	-	-	-	-
PW-7	12/16/1988	BCL	470	300	8.7	-	17.9	1	<1	106	1	24	45	140	<1	-	-	-	<0.1	-	<0.05	<0.01	-	-	-
PW-7	12/6/1989	UNK	510	350	8.8	-	-	1.1	0.12	112	0.6	18	60.9	153	-	-	-	-	-	-	-	0.011	-	-	-
PW-7	11/9/1990	UNK	-	335	8.2	-	-	-	-	-	0.6	-	52.5	188	-	-	-	0.12	-	-	-	0.018	-	-	-
PW-7	7/10/1991	UNK	600	365	8.7	-	-	-	-	-	0.7	-	60.2	195	-	-	-	-	-	-	-	-	-	-	-
PW-7	10/30/1991	UNK	610	365	8.8	-	-	1.3	0.14	138	0.7	14	72.7	207	-	0.23	-	0.17	-	-	-	-	-	-	-
PW-7	4/28/1992	UNK	650	360	8.5	-	-	2.1	-	-	0.7	-	74.8	218	-	-	-	-	-	-	-	-	-	-	-
PW-7	10/28/1992	UNK	720	420	8.4	-	-	2.3	0.2	160	0.9	24	69	241	-	0.09	-	0.12	-	-	-	0.013	-	-	-
PW-7	3/10/1993	UNK	640	435	8.4	-	-	-	-	-	0.9	-	74	324	-	-	-	-	-	-	-	-	-	-	-
PW-7	9/29/1993	UNK	700	390	8.5	-	-	1.8	0.16	159	1	19	85	245	-	0.22	-	0.18	-	-	-	-	-	-	-
PW-7	3/7/1994	UNK	740	445	8.5	-	-	2.4	0.25	169	0.9	28	73.8	266	-	0.09	-	-	-	-	-	-	-	-	-
PW-7	9/26/1994	UNK	827	480	8.5	-	-	3.3	0.3	183	1.1	22	88.8	294	-	-	-	-	-	-	-	-	-	-	-
PW-7	3/22/1995	UNK	-	-	-	-	-	2.3	0.21	179	-	19	-	-	-	0.22	-	0.2	-	-	-	0.011	-	-	-
PW-7	10/16/1995	UNK	764	450	8.6	-	-	2.1	0.19	165	0.8	15	92.6	269	-	0.26	-	0.2	-	-	-	-	-	-	-
PW-7	4/12/1996	UNK	734	510	8.5	-	-	2.6	0.22	162	0.9	22	86.5	243	-	0.2	-	0.23	-	-	-	0.012	-	-	-
PW-7	10/8/1996	UNK	737	430	8.44	-	-	2.2	0.21	169	0.9	14.8	86.8	246	-	0.26	-	0.2	-	-	-	0.011	-	-	-
PW-7	6/10/1997	UNK	906	548	8.6	-	-	4.6	0.5	200	1	29.5	95.8	281	-	0.07	-	0.12	-	-	-	0.026	-	-	-
PW-7	3/18/1998	UNK	860	530	8.3	-	-	3.4	0.3	210	1.7	18	100	260	-	-	-	0.24	0.05	-	-	0.01	-	-	-
PW-7	8/21/1998	UNK	910	440	8.3	-	-	3.9	0.42	210	5.5	20	120	290	ND	ND	-	0.2	ND	-	ND	ND	-	-	-
PW-7	4/22/1999	BSK	760	490	8.2	240	27.6	3.1	0.3	190	1	<20	94	293	<10	<1	<50	0.2	<0.05	-	<0.05	0.01	-	<40	-
PW-7	5/20/2000	BSK	890	560	8.3	290	24.4	4.1	0.3	190	<2	24	120	354	11	<1	<2	0.2	<0.05	-	<0.05	0.02	-	2	-
PW-7	12/18/2000	BSK	1000	560	8.1	290	19.5	5.5	0.6	180	<2	34	100	354	<12	<1.2	<2	0.1	<0.05	-	<0.05	0.03	-	<2	-
PW-7	6/4/2001	BSK	960	650	8.1	300	23.6	5.6	0.6	220	<2	35	120	366	<10	<1	<2	0.1	<0.05	-	<0.05	0.04	-	<2	-
PW-7	10/4/2001	UNK	1200	710	8.1	380	-	6.6	0.6	290	ND	ND	140	380	ND	ND	-	0.2	ND	-	ND	0.6	-	-	-
PW-7	5/3/2002	UNK	1200	740	8.0	370	-	5.7	0.5	250	ND	ND	140	370	ND	ND	-	0.2	ND	-	0.05	0.02	-	-	-
PW-7	12/11/2002	UNK	1200	680	8.0	360	-	5.7	0.5	240	ND	ND	140	360	ND	ND	-	0.2	ND	-	0.05	0.02	-	-	-
PW-7	3/23/2003	BSK	1100	600	8.1	320	-	7.5	0.8	200	-	41	120	-	-	ND	-	0.1	ND	-	0.1	0.05	-	-	-
PW-7	10/24/2003	BSK	1200	700	8.4	370	-	6.2	0.6	250	2	14	150	-	-	ND	-	0.2	ND	-	0.08	0.03	-	2	-
PW-7	3/31/2004	BSK	1000	670	8.4	370	-	6.9	0.8	250	<2	38	120	440	<4	<0.1	<2	0.1	<0.05	-	0.07	0.04	-	2	-
PW-7	11/15/2004	UNK	1200	740	8.3	420	-	7.4	0.8	280	ND	14	160	420	ND	0.3	-	0.2	ND	-	0.13	0.04	-	-	-
PW-7	4/6/2005	UNK	1100	660	8.2	370	-	42	7.4	200	2	54	130	370	ND	ND	-	0.1	0.09	-	ND	0.23	-	-	-
PW-7	10/13/2005	UNK	1100	660	8.4	360	-	6	0.6	230	ND	ND	140	340	ND	-	-	0.2	ND	-	0.11	0.04	-	-	-
PW-7	4/19/2006	BCL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.49	-	-	-	-	-	-	<0.34	-
PW-7	4/19/2006	DL	930	565	8.4	287	-	3.8	0.4	198	3.4	47.8	98.2	281	0.1	0.1	-	0.1	0.02	-	0.09	0.03	-	-	-
PW-7	9/26/2006	NA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<2	-	-	-	-	-	-	<2	-
PW-7	3/29/2007	TL	960	590	8.4	300	-	6.8	0.8	220	2.7	44	97	360	<6.2	-	<10	0.13	0.024	-	-	-	-	-	-
PW-7	9/23/2007	TL	1300	770	8.1	-	-	-	-	-	-	11	70	500	<10	-	-	-	-	-	-	-	-	-	-
PW-7	4/6/2008	BCL	1180	720	8.4	-	-	-	-	-	-	12	150	439	<0.4	-	-	-	-	-	-	-	-	-	-
PW-7	9/4/2008	BCL	1860	1200	7.9	-	-	-	-	-	-	14	250	769	<0.4	-	-	-	0.1	-	-	-	-	-	-
PW-7	4/3/2009	UNK	1080	690	8.5	-	-	-	-	-	-	35	130	330	ND	-	-	-	0.03	-	-	-	-	-	-
PW-7	10/5/2009	BSK	1700	970	8.3	-	-	-	-	-	-	<20	200	695	<10	-	-	-	-	-	-	-	-	-	-
PW-7	5/4/2011	SSC	1500	840	7.8	-	-	-	-	-	-	26	160	500	<2.2	-	-	-	-	-	-	-	-	-	-
PW-7	9/12/2011	SSC	1700	1000	7.7	-	-	-	-	-	-	13	210	590	<2.2	-	-	-	-	-	-	-	-	-	-
PW-7	4/23/2012	BCL	1430	920	8.09	-	-	-	-	-	-	25	160	573	<0.4	-	-	-	-	-	-	-	-	-	-
PW-7	10/4/2012	BCL	1120	720	8.13	-	-	-	-	-	-	49	130	427	0.36	-	-	-	-	-	-	-	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
DEEP (Spreckels)																									
PW-9	11/15/2004	UNK	1800	1100	7.8	560	-	36	4.7	370	ND	70	230	560	ND	ND	-	ND	0.15	-	0.1	0.44	-	-	-
PW-9	4/6/2005	UNK	1800	1100	8.0	420	-	28	3.3	390	3	36	360	420	ND	ND	-	0.3	0.12	-	ND	0.32	-	-	-
PW-9	10/13/2005	UNK	2300	1400	8.0	740	-	69	9.8	500	3	-	290	740	ND	-	-	ND	0.28	-	0.07	0.96	-	-	-
PW-9	4/19/2006	BCL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.49	-	-	-	-	-	-	4.2	-
PW-9	4/19/2006	DL	2566	1550	7.7	828	-	74.6	11.4	464	6.5	66	327	828	<0.1	<0.1	-	0.03	0.32	-	0.15	1.13	-	-	-
PW-9	9/26/2006	NA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<2	-	-	-	-	-	-	1.8	-
PW-9	3/29/2007	TL	2500	1600	7.1	810	-	79	14	490	14	65	310	990	<20	-	<10	0.092	0.5	-	-	-	-	-	-
PW-9	9/23/2007	TL	1700	1000	7.3	-	-	-	-	-	-	85	200	600	<20	-	-	-	-	-	-	-	-	-	-
PW-9	4/6/2008	BCL	2830	1800	7.23	-	-	-	-	-	-	52	370	1147	0.2	-	-	-	-	-	-	-	-	-	-
PW-9	9/4/2008	BCL	3340	2200	7.6	-	-	-	-	-	-	140	1200	1342	<0.4	-	-	-	1	-	-	-	-	-	-
PW-9	4/3/2009	UNK	3100	2000	7.3	-	-	-	-	-	-	64	450	1000	ND	-	-	-	0.93	-	-	-	-	-	-
PW-9	5/27/2009	FGL	2840	1710	6.8	790	15.8	62	12	519	26	44	450	970	<0.4	0.1	<2	0.2	0.419	<0.01	2.42	0.79	4	-	<0.02
PW-9	5/27/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
PW-9	10/15/2009	BSK	3100	1700	7.8	-	-	-	-	-	-	62	420	1342	<20	-	-	-	-	-	-	-	-	-	-
PW-9	5/4/2011	SSC	4100	2400	7.0	-	-	-	-	-	-	49	520	1400	<2.2	-	-	-	-	-	-	-	-	-	-
PW-9	7/19/2011	SSC	3000	1700	7.0	-	-	-	-	-	-	28	810	500	<2.2	-	-	-	-	-	-	-	-	-	-
PW-9	9/12/2011	SSC	3200	1900	7.1	-	-	-	-	-	-	68	420	1000	<2.2	-	-	-	-	-	-	-	-	-	-
PW-9	4/23/2012	BCL	3230	2000	7.42	-	-	-	-	-	-	55	440	1220	<2.2	-	-	-	-	-	-	-	-	-	-
PW-9	10/4/2012	BCL	2630	1700	7.44	-	-	-	-	-	-	70	360	1013	<0.9	-	-	-	-	-	-	-	-	-	-
PW-9	5/7/2013	BCL	2900	1800	7.6	-	-	-	-	-	-	63	410	950	<2.2	-	-	-	-	-	-	-	-	-	-
PW-9	10/24/2013	BCL	2550	1600	7.5	-	-	-	-	-	-	51	420	670	<2.2	-	-	-	-	-	-	-	-	-	-
PW-9	5/16/2014	BCL	2610	1500	8.2	-	-	-	-	-	-	64	420	700	1.2	-	-	-	-	-	-	-	-	-	-
PW-9	10/16/2014	BCL	-	1700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PW-9	10/17/2014	BCL	2590	1500	7.5	-	-	-	-	-	-	41	540	470	2.4	-	-	-	-	-	-	-	-	-	-
PW-10	12/14/1988	BCL	690	430	8.4	-	10.2	11	2	140	1	35	87	198	3	0.2	<10	-	<0.1	-	0.12	0.05	-	<5	-
PW-10	12/6/1989	UNK	680	420	8.5	-	-	5.3	0.63	140	0.8	35	75.4	195	-	-	-	-	-	-	-	0.021	-	-	-
PW-10	11/9/1990	UNK	-	445	8.1	-	-	-	-	-	1	-	75.5	230	-	-	-	0.19	-	-	-	0.026	-	-	-
PW-10	7/9/1991	UNK	750	455	8.4	-	-	-	-	-	1.2	-	81.5	252	-	-	-	-	-	-	-	-	-	-	-
PW-10	10/29/1991	UNK	720	445	8.5	-	-	11	1.4	147	1.1	30	86.9	237	-	0.19	-	0.18	-	-	-	0.044	-	-	-
PW-10	10/30/1991	UNK	720	445	8.5	-	-	11	1.4	147	1.1	30	86.9	237	-	0.19	-	0.18	-	-	-	44	-	-	-
PW-10	4/28/1992	UNK	840	455	8.2	-	-	20	-	-	1.5	-	92.5	298	-	-	-	-	-	-	-	-	-	-	-
PW-10	10/28/1992	UNK	800	500	8.1	-	-	19.1	2.6	157	1.5	32	86	299	-	0.13	-	0.16	-	-	-	0.079	-	-	-
PW-10	3/11/1993	UNK	920	540	8.0	-	-	-	-	-	1.9	-	99.1	358	-	-	-	-	-	-	-	-	-	-	-
PW-10	9/29/1993	UNK	900	500	8.0	-	-	25	3.8	176	1.8	37	99	336	-	0.07	-	0.12	-	-	0.075	0.109	-	-	-
PW-10	3/7/1994	UNK	880	530	8.0	-	-	23	3.5	175	1.7	40	94.3	325	-	0.05	-	-	-	-	-	-	-	-	-
PW-10	9/26/1994	UNK	922	540	8.0	-	-	24	3.8	173	1.8	38	94.2	336	-	-	-	-	-	-	-	-	-	-	-
PW-10	3/22/1995	UNK	-	-	-	-	-	37	5.7	200	-	40	-	-	-	-	-	-	-	-	-	0.172	-	-	-
PW-10	10/16/1995	UNK	850	470	8.2	-	-	15.5	2.6	165	1.3	33	102	268	-	0.19	-	0.19	-	-	0.062	0.077	-	-	-
PW-10	4/12/1996	UNK	843	605	8.5	-	-	15	2.2	166	1.3	39	97.6	269	-	0.15	-	0.22	-	-	-	0.066	-	-	-
PW-10	10/8/1996	UNK	867	490	8.5	-	-	17	2.8	178	1.5	31.5	108	296	-	0.19	-	0.19	-	-	0.056	0.076	-	-	-
PW-10	6/10/1997	UNK	942	565	8.0	-	-	25	3.8	178	1.6	36.4	102	349	-	0.11	-	0.16	-	-	-	0.129	-	-	-
PW-10	4/22/1999	BSK	820	510	8.2	250	10.5	18	2.7	180	3	40	99	305	<10	<1	<50	0.1	0.05	-	0.06	0.08	-	<40	-
PW-10	5/20/2000	BSK	840	510	7.9	250	10.4	18	2.8	180	<2	39	110	305	<10	<1	<2	0.2	<0.05	-	<0.05	0.08	-	2	-
PW-10	12/18/2000	BSK	930	520	8.0	240	9.8	16	2.6	160	<2	37	110	293	<10	<1	<2	0.2	<0.05	-	0.06	0.07	-	2	-
PW-10	6/4/2001	BSK	910	590	7.8	260	9.6	21	3.5	180	<2	41	120	317	<10	<1	<2	0.2	<0.05	-	<0.05	0.11	-	2	-
PW-10	10/4/2001	UNK	890	540	7.8	250	-	19	3.2	190	ND	40	120	250	62	ND	-	0.2	ND	-	ND	0.09	-	-	-
PW-10	5/3/2002	UNK	1100	660	7.7	330	-	45	7.5	170	2	60	120	330	ND	ND	-	0.1	0.09	-	ND	0.24	-	-	-

Table E-3 (continued)
Summary of Groundwater Quality Laboratory Results (Spreckels Sugar Co. and Meyers Farm Water Bank)

								Cations				Anions					Trace Elements								
Well Owner and Name	Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mgL)	pH	Total Alkalinity[3] (mg/L)	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Ba (mg/L)	Cu (mg/Ll)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
DEEP (Spreckels)																									
PW-11	10/24/2013	BCL	652	420	8.7	-	-	-	-	-	-	81	74	100	<0.4	-	-	-	-	-	-	-	-	-	-
PW-11	5/16/2014	BCL	592	360	8.6	-	-	-	-	-	-	93	46	110	<0.4	-	-	-	-	-	-	-	-	-	-
PW-11	10/16/2014	BCL	-	270	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PW-11	10/17/2014	BCL	617	360	8.7	-	-	-	-	-	-	98	50	110	ND	-	-	-	-	-	-	-	-	-	-
PW-12	3/31/2004	BSK	510	320	8.7	110	-	0.9	<0.1	78	<2	51	34	120	<4	<0.1	<2	<0.1	<0.05	-	0.06	<0.01	-	<2	-
PW-12	11/15/2004	UNK	600	380	8.7	130	-	2.7	0.3	130	ND	97	42	120	ND	ND	-	ND	ND	-	ND	ND	-	-	-
PW-12	4/6/2005	UNK	590	360	8.7	130	-	3.3	0.3	130	ND	100	47	120	ND	ND	-	ND	ND	-	ND	0.01	-	-	-
PW-12	10/14/2005	UNK	360	230	8.5	96	-	0.3	ND	75	ND	54	18	89	ND	ND	-	ND	ND	-	0.07	ND	-	-	-
PW-12	4/19/2006	BCL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.49	-	-	-	-	-	-	<0.34	-
PW-12	4/19/2006	DL	455	280	8.6	94.8	-	0.5	<0.1	104	1.6	50.6	51.4	94.8	0.1	0.1	-	0.08	<0.01	-	0.05	<0.01	-	-	-
PW-12	9/26/2006	NA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	<2	-
PW-12	3/29/2007	TL	780	480	8.6	170	-	5.4	0.53	170	1.8	100	68	200	<6.2	-	<10	0.063	0.012	-	-	-	-	-	-
PW-12	9/23/2007	TL	780	510	8.5	-	-	-	-	-	-	110	74	190	<6	-	-	-	-	-	-	-	-	-	-
PW-12	4/6/2008	BCL	825	510	8.65	-	-	-	-	-	-	110	78	183	<0.4	-	-	-	-	-	-	-	-	-	-
PW-12	9/4/2008	BCL	843	530	8.6	-	-	-	-	-	-	110	87	195	<0.4	-	-	-	0.012	-	-	-	-	-	-
PW-12	10/5/2009	BSK	900	520	8.7	-	-	-	-	-	-	110	90	207	<2	-	-	-	-	-	-	-	-	-	-
PW-12	5/4/2011	SSC	1000	590	8.5	-	-	-	-	-	-	97	100	220	<2.2	-	-	-	-	-	-	-	-	-	-
PW-12	9/12/2011	SSC	1000	620	8.5	-	-	-	-	-	-	100	110	230	<2.2	-	-	-	-	-	-	-	-	-	-
PW-12	4/23/2012	BCL	1070	680	8.51	-	-	-	-	-	-	100	120	281	<0.4	-	-	-	-	-	-	-	-	-	-
PW-12	10/4/2012	BCL	1090	720	8.44	-	-	-	-	-	-	110	130	305	<0.4	-	-	-	-	-	-	-	-	-	-
PW-12	5/7/2013	BCL	1110	720	8.5	-	-	-	-	-	-	110	130	250	<0.4	-	-	-	-	-	-	-	-	-	-
PW-12	10/24/2013	BCL	1210	770	8.4	-	-	-	-	-	-	110	140	280	<0.9	-	-	-	-	-	-	-	-	-	-
PW-12	5/16/2014	BCL	1260	760	8.6	-	-	-	-	-	-	120	150	270	<0.9	-	-	-	-	-	-	-	-	-	-
PW-12	10/16/2014	BCL	-	520	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PW-12	10/17/2014	BCL	1250	740	8.3	-	-	-	-	-	-	120	120	280	ND	-	-	-	-	-	-	-	-	-	-
DEEP (Meyers Farm)																									
DW-1	12/21/2007	BCL	2400	1400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DW-1	4/17/2008	BCL	2000	1100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DW-1	4/21/2008	BCL	-	-	-	-	-	-	-	-	-	-	-	280	-	-	-	-	-	-	-	-	-	-	-
DW-1	4/21/2008	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.46	<0.4	-
DW-1	10/4/2008	BCL	1970	1100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DW-1	7/22/2009	BCL	2940	1800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.079	-	-	-	-	-	-

1. Laboratory Abbreviations: AT - Agri Tech, Inc., Kerman; BD - Betz Dearborn; BCL - BC Laboratories, Bakersfield; BD - Betz Dearborn; BSK - BSK Analytical Laboratories, Fresno; CLS - California Laboratory Services, Rancho Cordova; FGL - Fruit Growers Laboratory, Santa Paula; JML - JM Lord, Fresno; JML(1) - JM Lord, Fresno (TDS estimated from EC); OBL = Olson Biochemistry Laboratories of South Dakota State University, Brookings, SD; TL - The Twining Laboratories, Inc., Fresno.; UAG - U.S. Agricultural Consultants and Laboratories, Burbank; USGS - U.S. Geological Survey

2. Electrical Conductivity at 25°C

3. HCO3, Total Alkalinity and NO3 reported as HCO3, CaCO3 and NO3 respectively. Some 2008 NO3 results may include NO2 in reported value.

NA = Not Available; ND = Non Detect (detection limit unknown)

Attachment E - Table G-1 of the 2016 Annual Report Mendota Pool Group Pumping and Monitoring Program

Table G-1 (continued)
Surface-Water Quality Laboratory Results

						Cations				Anions						Trace Elements							
Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	Total Alkalinity[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
MWA (Refuge)																							
6/24/2013	FGL	734	462	8.3	-	27	14	104	3	75	98	140	110	0.9	<0.1	2	0.3	<0.01	0.22	0.05	4	<1	<0.02
7/26/2013	FGL	905	554	8.4	-	24	12	143	3	93	129	150	120	<0.4	<0.1	3	0.3	<0.01	0.14	0.06	-	-	<0.02
8/31/2013	FGL	728	463	8.4	-	27	15	118	3	72	108	120	100	<0.4	<0.1	2	0.3	<0.01	0.2	0.06	-	-	0.08
10/2/2013	FGL	840	552	8.3	-	26	16	130	3	96	141	140	110	<0.4	<0.1	2	0.3	<0.01	0.31	0.06	4	1.64	0.02
5/20/2014	FGL	1450	969	8.4	-	34	15	243	4	201	222	250	200	<0.4	<0.1	3	0.6	<0.01	0.35	0.07	-	-	<0.02
6/30/2014	FGL	888	566	8.3	-	35	19	120	4	105	143	140	110	<0.4	0.1	3	0.4	<0.01	0.24	0.05	6	-	0.04
6/30/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.499	-
7/30/2014	FGL	1390	890	7.8	-	38	19	224	5	182	232	190	160	<0.4	0.1	-	0.5	<0.01	0.24	0.07	-	-	0.03
8/28/2014	FGL	1470	930	8.0	-	36	20	255	4	180	255	180	150	<0.4	<0.1	-	0.5	<0.01	0.17	0.05	-	-	<0.02
9/16/2014	FGL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	5	-	-
9/16/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
10/31/2014	FGL	1000	647	8.0	-	36	21	145	4	118	173	150	120	<0.5	<0.1	-	0.4	<0.01	0.23	0.08	-	-	0.03
5/18/2015	FGL	1640	1080	8.3	8.7	44	22	282	5	214	255	260	210	<0.5	0.2	-	0.6	<0.01	0.24	0.08	-	-	0.03
6/23/2015	FGL	1090	729	7.8	6.1	34	17	174	4	138	192	170	140	<0.5	0.3	2	0.4	<0.01	0.88	0.08	4	-	0.04
6/23/2015	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
7/30/2015	FGL	1400	882	8.2	-	40	19	231	4	176	232	180	150	<0.5	0.2	-	0.5	<0.01	0.19	0.06	-	-	0.06
8/13/2015	FGL	1620	1030	8.1	-	40	19	275	4	216	294	180	150	<0.5	0.3	-	0.5	<0.01	0.53	0.1	-	-	<0.02
9/15/2015	FGL	1530	913	7.7	8.1	37	17	237	4	197	241	180	140	<2.7	0.2	<2	0.5	<0.01	0.28	0.07	6	-	<0.02
9/15/2015	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
10/1/2015	FGL	1580	948	7.9	8.9	42	20	280	5	201	250	150	120	<0.4	0.1	-	0.6	<0.01	0.4	0.12	-	-	0.04
11/18/2015	FGL	1240	727	7.3	-	37	19	171	5	142	202	150	120	0.9	0.1	-	0.5	<0.01	0.4	0.07	-	-	0.09
4/15/2016	FGL	1530	981	7.3	-	43	20	259	5	215	238	200	170	0.6	0.1	-	0.5	<0.01	0.54	0.13	-	-	<0.02
5/18/2016	FGL	1400	941	7.8	-	41	17	237	4	215	244	180	150	2.7	0.2	-	0.5	<0.01	0.63	0.07	-	-	<0.02
6/30/2016	FGL	879	541	7.8	-	26	13	124	3	102	153	120	100	<0.4	0.1	<2	0.3	<0.01	0.24	0.05	4	-	<0.02
6/30/2016	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
7/28/2016	FGL	1020	628	8.1	-	27	13	155	3	119	181	130	100	<0.4	<0.1	-	0.3	<0.01	0.22	0.04	-	-	<0.02
8/2/2016	FGL	-	-	-	-	-	-	-	-	102	153	-	-	-	-	-	-	-	-	-	-	-	-
8/19/2016	FGL	1070	652	7.0	-	28	12	170	3	126	193	120	100	<0.4	0.1	-	0.3	<0.01	0.43	0.06	-	-	<0.02
9/20/2016	FGL	1080	649	5.2	-	29	14	168	3	121	184	130	110	<0.5	0.2	-	0.3	<0.01	0.26	0.08	-	-	0.03
9/29/2016	FGL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	2	-	-
9/29/2016	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
10/24/2016	FGL	915	542	7.8	-	26	15	130	4	85.5	162	120	100	<0.4	<0.1	-	0.2	<0.01	0.33	0.09	-	-	0.03
11/2/2016	FGL	1080	661	7.7	-	30	16	173	4	120	188	130	110	<0.4	<0.1	-	0.3	<0.01	0.27	0.1	-	-	0.04
James ID Booster Plant																							
10/25/2000	FGL	836	537	8.2	5.2	26	13	131	3	83	131	150	120	<0.4	0.1	-	0.34	<0.01	0.44	0.01	-	-	<0.02
11/18/2000	FGL	710	449	8.4	4.2	24	13	102	3	65	102	140	110	<0.4	<0.1	-	0.25	<0.01	0.13	<0.01	-	-	<0.02
12/15/2000	FGL	848	533	8.2	6	21	10	133	3	84	122	160	130	<0.4	0.1	-	0.38	<0.01	0.4	<0.01	-	-	<0.02
1/31/2001	FGL	710	450	8.2	4.2	24	12	102	3	60	109	140	110	<0.4	0.1	-	0.3	<0.01	0.34	<0.01	-	-	<0.02
3/28/2001	FGL	805	510	8.6	4.1	30	15	110	4	90	131	110	110	1.4	<0.1	-	0.35	<0.01	0.16	<0.01	-	-	<0.02
4/25/2001	FGL	826	550	8.4	6.4	27	5	138	7	53	107	210	170	4.5	0.2	-	0.37	0.02	0.12	0.01	-	-	<0.02
5/30/2001	FGL	824	540	8.7	5.7	29	5	126	6	53	125	190	170	4.2	0.1	10	0.38	<0.01	0.32	0.02	8	<2	<0.02
6/26/2001	FGL	784	514	8.7	4.4	27	13	110	3	94	117	150	120	<0.4	0.2	2	0.29	<0.01	0.56	0.05	5	1	<0.02
7/19/2001	FGL	665	442	8.6	3.8	26	14	96	3	72	91	140	110	<0.4	0.1	-	0.23	<0.01	1.17	0.06	-	-	<0.02
7/19/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<3	-	-	-	-	4.9	0.57	-

Table G-1 (continued)
Surface-Water Quality Laboratory Results

						Cations				Anions						Trace Elements							
Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	Total Alkalinity[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
James ID Booster Plant																							
8/15/2001	FGL	687	440	8.5	3.9	25	14	97	3	66	109	130	110	<0.4	0.1	3	0.21	<0.01	0.51	0.05	3	<2	<0.02
9/20/2001	FGL	1030	656	8.2	5.6	30	19	160	4	99	174	170	140	<0.4	0.2	3	0.28	<0.01	0.69	0.04	5	2	<0.02
11/5/2001	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7	0.59	-
11/5/2001	FGL	933	580	8.4	4.8	28	17	131	4	81	161	160	-	<0.4	0.2	<2	0.27	<0.01	0.23	0.01	-	-	<0.02
6/5/2002	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0.95	-
6/5/2002	FGL	708	440	8.0	3.4	26	15	88	4	70	99	140	120	1.3	<0.1	-	0.25	<0.01	0.38	0.02	-	-	<0.02
7/9/2002	FGL	463	300	8.3	2.4	21	11	54	3	44	54	110	90	0.9	<0.1	-	0.22	<0.01	0.63	0.02	-	-	0.06
7/15/2002	FGL	530	320	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<2	-
7/25/2002	FGL	512	310	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8/9/2002	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.2	0.64	-
8/9/2002	FGL	672	420	7.7	2.5	22	13	88	3	54	109	130	100	<0.4	<0.1	2	0.13	<0.01	0.33	0.03	-	-	0.02
8/14/2002	FGL	666	390	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8/19/2002	FGL	671	400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9/8/2002	FGL	737	470	8.1	3.6	24	14	110	3	55	134	130	100	<0.4	<0.1	-	0.22	<0.01	0.31	0.2	-	-	<0.02
9/20/2002	FGL	860	510	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9/20/2002	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.5	0.69	-
9/27/2002	FGL	935	560	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
10/4/2002	FGL	940	587	8.1	5.3	27	16	140	4	80	160	160	130	<0.4	<0.1	2	0.25	<0.01	0.18	0.01	-	-	<0.02
10/11/2002	FGL	893	530	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10/17/2002	FGL	874	510	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11/4/2002	FGL	755	423	8.4	3.6	24	17	94	4	52	112	120	100	<0.4	<0.1	<2	0.19	<0.01	0.16	0.01	-	-	<0.02
11/4/2002	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.3	<0.4	-
12/26/2002	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.2	0.61	-
12/26/2002	FGL	719	430	8.1	3.7	24	15	94	4	45	128	120	100	<0.4	0.1	<2	0.21	<0.01	0.05	<0.01	-	-	0.02
1/20/2003	FGL	691	418	8.1	3.2	24	16	83	5	41	129	120	100	<0.4	<0.1	<2	0.19	<0.01	0.44	<0.01	-	-	<0.02
1/20/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
1/31/2003	FGL	674	380	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2/25/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.15	0.973	-
3/23/2003	FGL	730	474	8.6	3.4	30	16	93	4	91	100	140	120	<0.4	<0.1	-	0.33	<0.01	0.13	<0.01	-	-	<0.02
3/26/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.05	-	-
4/27/2003	FGL	917	606	8.0	4.2	36	19	124	4	118	134	170	140	1.4	<0.1	-	0.42	<0.01	0.53	<0.01	-	-	<0.02
5/29/2003	FGL	769	501	8.7	3.9	30	15	105	4	98	109	140	120	<0.4	<0.1	-	0.33	<0.01	0.11	<0.01	-	-	<0.02
6/21/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.55	0.71	-
6/21/2003	FGL	342	224	7.8	1.7	19	9	35	2	33	35	90	70	0.8	0.2	2	0.17	<0.01	0.41	0.03	-	-	<0.02
7/18/2003	FGL	406	276	8.2	2.4	19	9	50	2	44	52	100	80	<0.4	0.2	2	0.18	<0.01	0.57	0.03	-	-	<0.02
8/27/2003	FGL	370	232	7.8	1.9	17	9	38	2	32	44	90	80	<0.4	0.2	-	0.15	<0.01	0.4	0.03	-	-	<0.02
9/18/2003	FGL	454	297	8.3	2.3	20	11	52	2	43	59	110	90	<0.4	0.2	-	0.2	<0.01	0.27	0.02	-	-	<0.02
10/29/2003	FGL	543	344	7.4	2.6	22	13	63	3	41	82	120	100	<0.4	0.2	<2	0.2	<0.01	0.27	0.02	-	-	<0.02
10/29/2003	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.2	<0.4	-
3/26/2004	FGL	723	470	8.5	3	34	17	87	4	105	92	120	120	0.5	0.1	3	0.3	<0.01	0.16	0.04	-	-	<0.02
3/26/2004	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.12	1.12	-
4/28/2004	FGL	802	533	7.9	3.5	35	18	101	4	109	106	160	140	<0.4	0.2	<2	0.4	<0.01	0.15	0.01	-	-	<0.02
5/24/2004	FGL	696	451	8.3	3.2	29	15	86	3	82	96	140	110	<0.4	0.2	-	0.3	<0.01	0.3	0.02	-	-	<0.02
6/18/2004	FGL	651	436	8.5	3	32	17	85	3	86	93	120	100	<0.4	0.2	2	0.3	<0.01	0.74	0.02	-	-	<0.02
10/29/2004	FGL	571	374	8.1	2.8	23	13	67	3	46	102	120	100	<0.4	0.3	<2	0.2	<0.01	0.17	0.02	-	-	<0.02

Table G-1 (continued)
Surface-Water Quality Laboratory Results

						Cations				Anions						Trace Elements							
Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	Total Alkalinity[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
James ID Booster Plant																							
10/29/2004	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.1	0.458	-
5/21/2007	FGL	1020	668	8.5	6.2	31	16	170	4	119	138	190	170	<0.4	0.3	-	0.43	<0.01	0.58	0.05	-	-	<0.02
6/25/2007	FGL	775	462	8.7	4	24	13	99	2	94	100	120	120	<0.4	<0.1	3	0.27	<0.01	0.25	0.03	-	-	<0.02
6/25/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.7	0.786	-
7/22/2007	FGL	712	474	7.4	4.4	23	12	105	3	83	98	150	130	<0.4	<0.1	3	0.26	<0.01	0.43	0.04	-	-	<0.02
8/13/2007	FGL	740	498	7.5	4.9	23	13	118	3	75	106	160	130	<0.4	0.2	3	0.23	<0.01	0.82	0.04	-	-	<0.02
9/18/2007	FGL	911	570	8.2	5.8	24	14	144	3	87	138	160	130	<0.4	0.2	2	0.27	<0.01	0.45	0.2	-	-	<0.02
9/18/2007	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.9	0.44	-
10/30/2007	FGL	1070	692	8.2	7	27	15	183	4	104	169	190	160	<0.4	0.2	-	0.3	<0.01	0.33	0.01	-	-	<0.02
6/23/2008	FGL	906	721	8.2	5.4	28	15	142	3	94	137	300	240	1.2	0.4	3	0.3	<0.01	0.58	0.04	-	-	<0.02
6/23/2008	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.85	0.67	-
7/14/2008	FGL	820	477	8.4	4.2	27	15	110	3	97	115	100	100	<0.4	0.3	4	0.3	<0.01	0.52	0.03	-	-	<0.02
8/26/2008	FGL	1000	656	6.8	6.3	27	14	161	3	140	141	170	140	<0.4	0.2	4	0.5	<0.01	0.34	0.03	-	-	<0.02
9/17/2008	FGL	1000	625	7.2	5.6	29	16	150	3	111	156	160	130	<0.4	0.2	3	0.4	<0.01	0.36	0.03	-	-	<0.02
9/17/2008	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.73	<0.4	-
10/13/2008	FGL	1120	677	7.6	6.1	28	16	164	4	110	185	170	140	<0.4	0.1	3	0.4	<0.01	0.3	0.01	-	-	<0.02
4/16/2009	FGL	1270	852	8.4	6.6	41	21	208	4	154	194	230	190	<0.4	0.2	-	0.5	<0.01	0.32	0.01	-	-	<0.02
5/14/2009	FGL	1640	1030	8.3	18.3	20	3	332	6	35	356	280	230	0.8	0.6	8	1.6	<0.01	0.43	0.03	-	-	<0.02
6/30/2009	FGL	841	548	8.2	4.5	29	15	121	3	105	125	150	120	<0.4	0.2	2	0.4	<0.01	0.67	0.04	5	-	<0.02
6/30/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.42	-
7/23/2009	FGL	662	425	8.3	4	23	12	96	3	72	89	130	110	<0.4	0.2	3	0.3	<0.01	0.47	0.04	-	-	<0.02
8/6/2009	FGL	723	497	8.2	4.9	23	11	115	3	97	108	140	120	<0.4	0.2	3	0.3	<0.01	0.47	0.03	-	-	<0.02
8/30/2009	FGL	1000	640	7.9	6.6	26	13	164	3	107	157	170	140	<0.4	0.2	3	0.3	<0.01	0.27	0.02	-	-	<0.02
9/25/2009	FGL	1060	689	8.1	6.8	28	15	180	3	132	171	160	130	<0.4	0.2	3	0.4	<0.01	0.4	0.02	7	-	<0.02
9/25/2009	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
10/26/2009	FGL	993	618	7.8	5.9	27	15	154	4	116	162	140	120	<0.4	0.2	2	0.3	<0.01	0.28	0.01	-	-	<0.02
5/28/2010	FGL	960	614	8.2	5.2	32	16	145	3	134	144	140	120	<0.4	0.1	3	0.4	<0.01	0.27	0.01	-	-	<0.02
6/7/2010	FGL	862	566	8.6	4.8	31	16	132	3	120	124	140	110	<0.4	0.1	3	0.4	<0.01	0.4	0.02	-	-	<0.02
6/7/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.484	-
6/28/2010	FGL	410	262	8.1	2.3	19	9	49	2	53	50	80	70	<0.4	<0.1	2	0.2	<0.01	0.38	0.03	-	-	<0.02
7/9/2010	FGL	469	302	8.0	2.6	21	10	58	2	57	64	90	70	<0.4	<0.1	3	0.2	<0.01	0.44	0.04	-	-	<0.02
8/29/2010	FGL	555	349	7.8	3.3	22	11	76	2	58	80	100	80	<0.4	<0.1	3	0.2	<0.01	0.44	0.04	-	-	<0.02
9/24/2010	FGL	641	409	8.6	3.7	24	12	88	3	93	89	100	90	<0.4	0.1	2	0.3	<0.01	0.34	0.03	-	-	<0.02
9/24/2010	OBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.06	<0.4	-
10/15/2010	FGL	646	388	7.9	3.5	23	13	85	3	53	111	100	80	<0.4	<0.1	<2	0.2	<0.01	0.23	0.02	-	-	<0.02
5/9/2012	FGL	1480	1040	8.4	-	40	19	256	5	240	236	240	190	<1.8	0.3	6	0.6	<0.01	0.28	0.02	-	-	<0.02
6/6/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.4	-
6/6/2012	FGL	773	501	8.2	-	29	15	112	3	103	109	130	110	<1.8	0.1	3	0.4	<0.01	0.34	0.04	4	-	<0.02
7/19/2012	FGL	774	519	8.2	-	26	12	122	3	129	107	120	100	<1.8	0.1	4	0.4	<0.01	0.43	0.04	-	-	0.02
9/23/2012	BAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
9/24/2012	FGL	935	597	8.2	-	25	12	151	3	139	137	130	110	<1.8	0.1	4	0.4	<0.01	0.18	0.01	7	-	<0.02
10/29/2012	FGL	993	614	8.0	-	28	16	151	4	99	166	150	120	<1.8	<0.1	2	0.3	<0.01	0.11	0.02	-	-	0.02
5/31/2013	FGL	1180	760	8.3	-	35	17	188	3	149	178	190	160	<0.4	0.1	3	0.5	<0.01	0.46	0.03	-	-	0.03
6/24/2013	FGL	852	535	8.3	-	30	16	130	3	87	119	150	120	<0.4	<0.1	2	0.4	<0.01	0.37	0.04	4	<1	<0.02
7/26/2013	FGL	876	562	8.3	-	27	12	141	3	125	104	150	120	<0.4	0.1	4	0.4	<0.01	0.27	0.03	-	-	<0.02

Table G-1 (continued)
Surface-Water Quality Laboratory Results

Date	Lab[1]	EC[2] (µmhos/cm)	TDS (mg/L)	pH	SAR	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	HCO_3[3] (mg/L)	Total Alkalinity[3] (mg/L)	NO_3[3] (mg/L)	F (mg/L)	As (µg/L)	B (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Mo (µg/L)	Se (µg/L)	Zn (mg/L)
James ID Booster Plant																							
8/31/2013	FGL	919	642	8.2	-	32	17	174	4	100	145	170	140	<0.4	0.1	3	0.4	<0.01	0.6	<0.01	-	-	0.1
10/2/2013	FGL	939	597	8.3	-	28	15	143	3	115	142	150	120	0.4	0.2	3	0.4	<0.01	0.3	0.02	5	2.05	<0.02
5/20/2014	FGL	1560	985	8.6	-	18	2	301	5	64.2	335	260	220	<0.4	<0.1	8	1.5	<0.01	0.3	0.05	-	-	<0.02
6/30/2014	FGL	1080	701	8.1	-	37	18	165	4	134	173	170	140	<0.4	0.1	3	0.4	<0.01	0.38	0.04	7	-	0.03
6/30/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.458	-
7/30/2014	FGL	1150	736	7.9	-	38	19	171	5	150	173	180	140	<0.4	0.1	-	0.5	<0.01	0.33	0.03	-	-	0.03
8/28/2014	FGL	1550	993	7.9	-	41	22	266	5	196	263	200	170	<0.4	0.2	-	0.5	<0.01	0.17	0.02	-	-	0.02
9/16/2014	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
9/16/2014	FGL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	12	-	-
10/31/2014	FGL	1450	1020	7.9	-	33	10	285	5	320	179	190	150	0.4	0.5	-	1.1	<0.01	0.33	0.01	-	-	0.03
5/18/2015	FGL	1410	888	8.4	11.8	29	4	256	7	74	275	240	200	2.7	0.4	-	1.3	<0.01	0.07	0.03	-	-	<0.02
6/23/2015	FGL	1350	883	7.6	7.5	39	17	223	5	194	215	190	160	<0.5	0.3	4	0.6	<0.01	1.16	0.04	7	-	0.04
6/23/2015	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
7/30/2015	FGL	1320	833	8.2	-	31	13	228	5	108	258	190	160	<0.5	0.4	-	0.9	<0.01	0.21	0.02	-	-	0.04
8/13/2015	FGL	1380	897	8.2	-	34	16	232	5	158	252	200	170	<0.5	0.3	-	0.7	<0.01	0.57	0.03	-	-	<0.02
9/15/2015	FGL	1620	1000	7.9	10.2	32	13	272	5	260	222	200	170	<2.7	0.4	5	1	<0.01	0.41	0.02	13	-	<0.02
9/15/2015	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
10/1/2015	FGL	1560	967	8.1	10.8	32	10	272	5	300	177	170	140	0.4	0.6	-	1.2	<0.01	0.41	0.02	-	-	0.06
11/18/2015	FGL	1460	926	7.9	-	25	5	267	5	325	128	170	140	<0.4	0.7	-	1.2	<0.01	0.63	0.02	-	-	0.17
4/15/2016	FGL	749	498	7.7	-	25	4	127	5	41	101	190	160	4.4	0.3	-	0.4	<0.01	0.31	0.05	-	-	<0.02
5/18/2016	FGL	1580	1070	7.9	-	46	21	283	5	230	272	210	170	<0.4	0.2	-	0.6	<0.01	0.54	0.03	-	-	<0.02
6/30/2016	FGL	945	564	7.2	-	28	13	134	3	120	146	120	100	<0.4	0.2	3	0.4	<0.01	0.37	0.03	6	-	<0.02
6/30/2016	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
7/28/2016	FGL	855	534	7.9	-	26	12	124	3	97.6	151	120	100	<0.4	0.1	-	0.3	<0.01	0.21	0.02	-	-	0.02
8/19/2016	FGL	1030	630	5.4	-	33	13	157	4	130	163	130	100	<0.4	0.3	-	0.5	<0.01	0.29	0.03	-	-	0.06
9/20/2016	FGL	1500	938	8.2	-	14	2	294	5	46.6	306	270	220	<0.5	0.9	-	1.7	<0.01	0.51	0.05	-	-	<0.02
9/29/2016	FGL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	-	-	-	-	10	-	-
9/29/2016	SDAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	-
10/24/2016	FGL	828	562	7.4	-	25	6	133	14	58.8	101	220	180	4.1	0.2	-	0.4	<0.01	0.24	0.03	-	-	<0.02
11/2/2016	FGL	750	490	7.7	-	21	5	125	5	59.4	92	180	150	2.7	0.3	-	0.3	<0.01	0.24	0.02	-	-	0.02
Tranquillity ID Inlet																							
7/25/2002	FGL	540	320	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8/9/2002	FGL	712	410	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8/14/2002	FGL	703	420	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<2	-
8/19/2002	FGL	672	390	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<2	-
9/8/2002	FGL	1570	925	8.0	12.2	23	6	255	5	90	296	250	200	<0.4	0.2	-	1.29	0.01	0.05	0.12	-	3	<0.02
9/20/2002	FGL	1790	1080	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
9/27/2002	FGL	2240	1390	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10/4/2002	FGL	2370	1480	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
10/11/2002	FGL	2430	1510	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
10/17/2002	FGL	1330	770	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<2	<0.02
11/4/2002	FGL	977	580	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<2	-
1/31/2003	FGL	698	390	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<2	-
3/23/2003	FGL	728	473	7.9	3.1	30	17	86	4	94	101	140	120	-	<0.1	-	0.33	<0.01	0.31	0.02	-	-	<0.02

Attachment F - ***Water Quality for Agriculture*, Food and Agriculture Organization Irrigation and Drainage Paper 29 Rev**. 1 (1994, R.S. Ayers and D.W. Westcott

Water quality for agriculture

CONTENTS

Water quality for agriculture

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FAO IRRIGATION AND DRAINAGE PAPER

29 Rev. 1

Reprinted 1989, 1994

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M-56
ISBN 92-5-102263-1

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PREFACE

Water Quality for Agriculture was first published in 1976 as Irrigation and Drainage Paper 29. Although many of the basic concepts of salinity control and dealing with poor quality water remain the same, new data and experience have prompted us to revise the 1976 paper in order to keep the user up-to-date.

The document is now presented as a field guide for evaluating the suitability of a water for irrigation. Included are suggestions for obtaining maximum utilization of an existing or potential water supply. Guideline values given identify a potential problem water based on possible restrictions in use related to 1) salinity, 2) rate of water infiltration into the soil, 3) a specific ion toxicity, or 4) to some other miscellaneous effects. Discussions and examples are given along with possible management alternatives to deal with these potential problems.

This paper is intended to provide guidance to farm and project managers, consultants and engineers in evaluating and identifying potential problems related to water quality. It discusses possible restrictions on the use of the water and presents management options which may assist in farm or project management, planning and operation. The guidelines and discussions are based on reported experiences gained from many farm areas throughout the world, mostly in arid and semi-arid areas. A vast majority of the data has come from agriculture in the Western United States, therefore, caution and a critical attitude should be taken when applying the guidelines to specific local conditions. The guidelines can indicate potential problems and possible restrictions on use of the water but the true suitability of a given water depends on the specific conditions of use and on the management capability of the user. The guidelines should be useful in placing water quality effects in perspective with the other factors affecting crop production, the ultimate goal being to obtain maximum production per unit of available water.

Salinity is discussed from the standpoint of a reduction in soil-water availability to the crop. Recent research findings on plant response to salinity within the root zone have been incorporated into the guidelines to improve their predictive capability. Updated crop tolerance values have also become available and are included. A method is presented for calculating the leaching requirement for the crop considering the quality of water available. Values calculated by this procedure, if adopted, represent an appreciable water saving as compared to most older procedures.

A water infiltration problem related to water quality is usually associated with both the salinity and sodium content of the water. A procedure is presented to evaluate the potential of a water to cause an infiltration problem based on a combination of its salinity (EC_w) and sodium adsorption ratio (SAR).

A specific ion toxicity is discussed as to the concentration of boron, sodium or chloride and their effect on yield of sensitive crops. Other less frequently encountered problems are

discussed as miscellaneous problems. Tables showing recommended maximum concentrations of trace elements for irrigation water and for toxic substances in drinking water for livestock are also presented.

ACKNOWLEDGEMENTS

These guidelines are based on various preceding guidelines developed and used in irrigated agriculture in the Western United States. The format follows that used by the staff of the University of California, USA. Many of the basic data and the concepts of saline water use and management have been developed or proposed by the US Salinity Laboratory and the authors would like to express their grateful appreciation for this help, particularly to Drs. G.J. Hoffman, E.V. Maas, J.D. Rhoades, D.L. Suarez, and the Laboratory Director, J. van Schilfgaarde.

Drs. R.L. Branson and J.D. Oster (University of California), Dr. J. Van Hoorn (Wageningen), Mr. J.D. Doorenbos (Ministry of Agriculture, The Netherlands), and staff of the Land and Water Development Division (FAO) have been particularly helpful with suggestions and draft reviews. Thanks are also due to: Chrissi Smith-Redfern, Hazel Tonkin, Charlene Arora and Mary Westcot.

The paper is dedicated to the field person who must make decisions on the effective use of irrigation water. This paper attempts to take the solution and prevention of water quality problems to the field. The ultimate goal is that of maximum food production from the available supply of water.

NOTE:

In running text where symbols are used, e.g. ECdw, for mechanical reasons they have been typed level on the line. However, they appear correctly in the equations where greater flexibility is possible e.g. EC_{dw}.

Hyperlinks to non-FAO Internet sites do not imply any official endorsement of or responsibility for the opinions, ideas, data or products presented at these locations, or guarantee the validity of the information provided. The sole purpose of links to non-FAO sites is to indicate further information available on related topics.

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1. WATER QUALITY EVALUATION

1.1 INTRODUCTION

Irrigated agriculture is dependent on an adequate water supply of usable quality. Water quality concerns have often been neglected because good quality water supplies have been plentigul and readily available. This situation is now changing in many areas. Intensive use of nearly all good quality supplies means that new irrigation projects and old projects seeking new or supplemental supplies must rely on lower quality and less desirable sources. To avoid problems when using these poor quality water supplies, there must be sound planning to ensure that the quality of water available is put to the best use.

The objective of this paper is to help the reader to a better understanding of the effect of water quality upon soil and crops and to assist in selecting suitable alternatives to cope with potential water quality related problems that might reduce production under prevailing conditions of use.

Conceptually, water quality refers to the characteristics of a water supply that will influence its suitability for a specific use, i.e. how well the quality meets the needs of the user. Quality is defined by certain physical, chemical and biological characteristics. Even a personal preference such as taste is a simple evaluation of acceptability. For example, if two drinking waters of equally good quality are available, people may express a preference for one supply rather than the other; the better tasting water becomes the preferred supply. In irrigation water evaluation, emphasis is placed on the chemical and physical characteristics of the water and only rarely are any other factors considered important.

Specific uses have different quality needs and one water supply is considered more acceptable (of better quality) if it produces better results or causes fewer problems than an alternative water supply. For example, good quality river water which can be used successfully for irrigation may, because of its sediment load, be unacceptable for municipal use without treatment to remove the sediment. Similarly, snowmelt water of excellent quality for municipal use may be too corrosive for industrial use without treatment to reduce its corrosion potential.

The ideal situation is to have several supplies from which to make a selection, but normally only one supply is available. In this case, the quality of the available supply must be evaluated to see how it fits the intended use. Most of the experience in using water of different qualities has been gained from observations and detailed study of problems that develop following use. The cause and effect relationship between a water constituent and the observed problem then results in an evaluation of quality of degree of acceptability. With sufficient reported experiences and measured responses, certain constituents emerge as indicators of quality-related problems. These characteristics are then organized into guidelines related to suitability for use. Each new set of guidelines builds upon the previous set to improve the predictive capability. Numerous such guidelines have become available covering many types of use.

There have been a number of different water quality guidelines related to irrigated agriculture. Each has been useful but none has been entirely satisfactory because of the wide variability in field conditions. Hopefully, each new set of guidelines has improved our predictive capability. The guidelines presented in this paper have relied heavily on previous ones but are modified to give more practical procedures for evaluating and managing water quality-related problems of

irrigated agriculture. They are an updated version of those in the 1976 edition of this paper. Changes from the 1976 edition are discussed in the appropriate sections of the paper.

1.2 WATER QUALITY PROBLEMS

Water used for irrigation can vary greatly in quality depending upon type and quantity of dissolved salts. Salts are present in irrigation water in relatively small but significant amounts. They originate from dissolution or weathering of the rocks and soil, including dissolution of lime, gypsum and other slowly dissolved soil minerals. These salts are carried with the water to wherever it is used. In the case of irrigation, the salts are applied with the water and remain behind in the soil as water evaporates or is used by the crop.

The suitability of a water for irrigation is determined not only by the total amount of salt present but also by the kind of salt. Various soil and cropping problems develop as the total salt content increases, and special management practices may be required to maintain acceptable crop yields. Water quality or suitability for use is judged on the potential severity of problems that can be expected to develop during long-term use.

The problems that result vary both in kind and degree, and are modified by soil, climate and crop, as well as by the skill and knowledge of the water user. As a result, there is no set limit on water quality; rather, its suitability for use is determined by the conditions of use which affect the accumulation of the water constituents and which may restrict crop yield. The soil problems most commonly encountered and used as a basis to evaluate water quality are those related to salinity, water infiltration rate, toxicity and a group of other miscellaneous problems.

WATER QUALITY-RELATED PROBLEMS IN IRRIGATED AGRICULTURE

SALINITY

Salts in soil or water reduce water availability to the crop to such an extent that yield is affected.

WATER INFILTRATION RATE

Relatively high sodium or low calcium content of soil or water reduces the rate at which irrigation water enters soil to such an extent that sufficient water cannot be infiltrated to supply the crop adequately from one irrigation to the next.

SPECIFIC ION TOXICITY

Certain ions (sodium, chloride, or boron) from soil or water accumulate in a sensitive crop to concentrations high enough to cause crop damage and reduce yields.

MISCELLANEOUS

Excessive nutrients reduce yield or quality; unsightly deposits on fruit or foliage reduce marketability; excessive corrosion of equipment increases maintenance and repairs.

1.2.1 Salinity

A salinity problem exists if salt accumulates in the crop root zone to a concentration that causes a loss in yield. In irrigated areas, these salts often originate from a saline, high water table or from salts in the applied water. Yield reductions occur when the salts accumulate in the root zone to such an extent that the crop is no longer able to extract sufficient water from the salty soil solution, resulting in a water stress for a significant period of time. If water uptake is

appreciably reduced, the plant slows its rate of growth. The plant symptoms are similar in appearance to those of drought, such as wilting, or a darker, bluish-green colour and sometimes thicker, waxier leaves. Symptoms vary with the growth stage, being more noticeable if the salts affect the plant during the early stages of growth. In some cases, mild salt effects may go entirely unnoticed because of a uniform reduction in growth across an entire field.

Salts that contribute to a salinity problem are water soluble and readily transported by water. A portion of the salts that accumulate from prior irrigations can be moved (leached) below the rooting depth if more irrigation water infiltrates the soil than is used by the crop during the crop season. Leaching is the key to controlling a water quality-related salinity problem. Over a period of time, salt removal by leaching must equal or exceed the salt additions from the applied water to prevent salt building up to a damaging concentration. The amount of leaching required is dependent upon the irrigation water quality and the salinity tolerance of the crop grown.

Salt content of the root zone varies with depth. It varies from approximately that of the irrigation water near the soil surface to many times that of the applied water at the bottom of the rooting depth. Salt concentration increases with depth due to plants extracting water but leaving salts behind in a greatly reduced volume of soil water. Each subsequent irrigation pushes (leaches) the salts deeper into the root zone where they continue to accumulate until leached. The lower rooting depth salinity will depend upon the leaching that has occurred.

Following an irrigation, the most readily available water is in the upper root zone - a low salinity area. As the crop uses water, the upper root zone becomes depleted and the zone of most readily available water changes toward the deeper parts as the time interval between irrigations is extended. These lower depths are usually more salty. The crop does not respond to the extremes of low or high salinity in the rooting depth but integrates water availability and takes water from wherever it is most readily available. Irrigation timing is thus important in maintaining a high soil-water availability and reducing the problems caused when the crop must draw a significant portion of its water from the less available, higher salinity soil-water deeper in the root zone. For good crop production, equal importance must be given to maintaining a high soil-water availability and to leaching accumulated salts from the rooting depth before the salt concentration exceeds the tolerance of the plant.

For crops irrigated infrequently, as is normal when using surface methods and conventional irrigation management, crop yield is best correlated with the average root zone salinity, but for crops irrigated on a daily, or near daily basis (localized or drip irrigation) crop yields are better correlated with the water-uptake weighted root zone salinity (Rhoades 1982). The differences are not great but may become important in the higher range of salinity. In this paper, discussions are based on crop response to the average root zone salinity.

In irrigated agriculture, many salinity problems are associated with or strongly influenced by a shallow water table (within 2 metres of the surface). Salts accumulate in this water table and frequently become an important additional source of salt that moves upward into the crop root zone. Control of an existing shallow water table is thus essential to salinity control and to successful long-term irrigated agriculture. Higher salinity water requires appreciable extra water for leaching, which adds greatly to a potential water table (drainage) problem and makes long-term irrigated agriculture nearly impossible to achieve without adequate drainage. If drainage is adequate, salinity control becomes simply good management to ensure that the crop is adequately supplied with water at all times and that enough leaching water is applied to control salts within the tolerance of the crop.

1.2.2 Water Infiltration Rate

An infiltration problem related to water quality occurs when the normal infiltration rate for the applied water or rainfall is appreciably reduced and water remains on the soil surface too long or infiltrates too slowly to supply the crop with sufficient water to maintain acceptable yields. Although the infiltration rate of water into soil varies widely and can be greatly influenced by the quality of the irrigation water, soil factors such as structure, degree of compaction, organic matter content and chemical make-up can also greatly influence the intake rate.

The two most common water quality factors which influence the normal infiltration rate are the salinity of the water (total quantity of salts in the water) and its sodium content relative to the calcium and magnesium content. A high salinity water will increase infiltration. A low salinity water or a water with a high sodium to calcium ratio will decrease infiltration. Both factors may operate at the same time. Secondary problems may also develop if irrigations must be prolonged for an extended period of time to achieve adequate infiltration. These include crusting of seedbeds, excessive weeds, nutritional disorders and drowning of the crop, rotting of seeds and poor crop stands in low-lying wet spots. One serious side effect of an infiltration problem is the potential to develop disease and vector (mosquito) problems.

An infiltration problem related to water quality in most cases occurs in the surface few centimetres of soil and is linked to the structural stability of this surface soil and its low calcium content relative to that of sodium. When a soil is irrigated with a high sodium water, a high sodium surface soil develops which weakens soil structure. The surface soil aggregates then disperse to much smaller particles which clog soil pores. The problem may also be caused by an extremely low calcium content of the surface soil. In some cases, water low in salt can cause a similar problem but this is related to the corrosive nature of the low salt water and not to the sodium content of the water or soil. In the case of the low salt water, the water dissolves and leaches most of the soluble minerals, including calcium, from the surface soil.

1.2.3 Toxicity

Toxicity problems occur if certain constituents (ions) in the soil or water are taken up by the plant and accumulate to concentrations high enough to cause crop damage or reduced yields. The degree of damage depends on the uptake and the crop sensitivity. The permanent, perennial-type crops (tree crops) are the more sensitive. Damage often occurs at relatively low ion concentrations for sensitive crops. It is usually first evidenced by marginal leaf burn and interveinal chlorosis. If the accumulation is great enough, reduced yields result. The more tolerant annual crops are not sensitive at low concentrations but almost all crops will be damaged or killed if concentrations are sufficiently high.

The ions of primary concern are chloride, sodium and boron. Although toxicity problems may occur even when these ions are in low concentrations, toxicity often accompanies and complicates a salinity or water infiltration problem. Damage results when the potentially toxic ions are absorbed in significant amounts with the water taken up by the roots. The absorbed ions are transported to the leaves where they accumulate during transpiration. The ions accumulate to the greatest extent in the areas where the water loss is greatest, usually the leaf tips and leaf edges. Accumulation to toxic concentrations takes time and visual damage is often slow to be noticed. The degree of damage depends upon the duration of exposure, concentration by the toxic ion, crop sensitivity, and the volume of water transpired by the crop. In a hot climate or hot part of the year, accumulation is more rapid than if the same crop were grown in a cooler climate or cooler season when it might show little or no damage.

Toxicity can also occur from direct absorption of the toxic ions through leaves wet by overhead sprinklers. Sodium and chloride are the primary ions absorbed through leaves, and toxicity to

one or both can be a problem with certain sensitive crops such as citrus. As concentrations increase in the applied water, damage develops more rapidly and becomes progressively more severe.

1.2.4 Miscellaneous

Several other problems related to irrigation water quality occur with sufficient frequency for them to be specifically noted. These include high nitrogen concentrations in the water which supplies nitrogen to the crop and may cause excessive vegetative growth, lodging, and delayed crop maturity; unsightly deposits on fruit or leaves due to overhead sprinkler irrigation with high bicarbonate water, water containing gypsum, or water high in iron; and various abnormalities often associated with an unusual pH of the water. A special problem faced by some farmers practising irrigation is deterioration of equipment due to water-induced corrosion or encrustation. This problem is most serious for wells and pumps, but in some areas, a poor quality water may also damage irrigation equipment and canals. In areas where there is a potential risk from diseases such as malaria, schistosomiasis and lymphatic filariasis, disease vector problems must be considered along with other water quality-related problems. Vector problems (mosquitoes) often originate as a secondary trouble related to a low water infiltration rate, to the use of wastewater for irrigation, or to poor drainage. Suspended organic as well as inorganic sediments cause problems in irrigation systems through clogging of gates, sprinkler heads and drippers. They can cause damage to pumps if screens are not used to exclude them. More commonly, sediments tend to fill canals and ditches and cause costly dredging and maintenance problems. Sediment also tends to reduce further the water infiltration rate of an already slowly permeable soil.

1.3 APPROACH TO EVALUATING WATER QUALITY

The prediction that a water quality-related problem will occur requires evaluation of the potential of the water to create soil conditions that may restrict its use or that may require the use of special management techniques to maintain acceptable yields. There are a number of procedures available for this evaluation but regardless of which one is used, emphasis should focus on relating the potential problem to the field situation since solutions to water quality problems usually must be implemented at the farm level rather than at the project level. The evaluation must therefore be done in terms of specific local conditions of use and the farm management capability of the water user.

This approach is the same as in the 1976 edition of this paper and similar guidelines are proposed for evaluating the potential of an irrigation water to create soil or crop problems. The guidelines are followed by suggestions on management alternatives to overcome these potential problems. This approach is often referred to as a problem-solving approach and emphasizes long-term effects on irrigated agriculture rather than short-term, because of the large investments now needed in irrigated agriculture.

The four problem categories previously discussed - **salinity, infiltration, toxicity** and **miscellaneous** - are used for evaluation. Water quality problems, however, are often complex and a combination of problems may affect crop production more severely than a single problem in isolation. The more complex the problem, the more difficult it is to formulate an economical management programme for solution.

If problems do occur in combination, they are more easily understood and solved if each factor is considered individually. Therefore, the guidelines and discussion which follow treat each problem and its solution separately, so that a number of factors are evaluated for each of the problem areas, such as:

- the type and concentration of salts causing the problem;
- the soil-water-plant interactions that may cause the loss in crop yield;
- the expected severity of the problem following long-term use of the water;
- the management options that are available to prevent, correct, or delay the onset of the problem.

1.4 WATER QUALITY GUIDELINES

Guidelines for evaluation of water quality for irrigation are given in Table 1. They emphasize the long-term influence of water quality on crop production, soil conditions and farm management, and are presented in the same format as in the 1976 edition but are updated to include recent research results. This format is similar to that of the 1974 University of California Committee of Consultant's Water Quality Guidelines which were prepared in cooperation with staff of the United States Salinity Laboratory.

The guidelines are practical and have been used successfully in general irrigated agriculture for evaluation of the common constituents in surface water, groundwater, drainage water, sewage effluent and wastewater. They are based on certain assumptions which are given immediately following the table. These assumptions must be clearly understood but should not become rigid prerequisites. A modified set of alternative guidelines can be prepared if actual conditions of use differ greatly from those assumed.

Ordinarily, no soil or cropping problems are experienced or recognized when using water with values less than those shown for 'no restriction on use'. With restrictions in the slight to moderate range, gradually increasing care in selection of crop and management alternatives is required if full yield potential is to be achieved. On the other hand, if water is used which equals or exceeds the values shown for severe restrictions, the water user should experience soil and cropping problems or reduced yields, but even with cropping management designed especially to cope with poor quality water, a high level of management skill is essential for acceptable production. If water quality values are found which approach or exceed those given for the severe restriction category, it is recommended that before initiating the use of the water in a large project, a series of pilot farming studies be conducted to determine the economics of the farming and cropping techniques that need to be implemented.

Table 1 is a management tool. As with many such interpretative tools in agriculture, it is developed to help users such as water agencies, project planners, agriculturalists, scientists and trained field people to understand better the effect of water quality on soil conditions and crop production. With this understanding, the user should be able to adjust management to utilize poor quality water better. However, the user of Table 1 must guard against drawing unwarranted conclusions based only on the laboratory results and the guideline interpretations as these must be related to field conditions and must be checked, confirmed and tested by field trials or experience.

The guidelines are a first step in pointing out the quality limitations of a water supply, but this alone is not enough; methods to overcome or adapt to them are also needed. Therefore, in subsequent sections, management alternatives are presented and several examples are given to illustrate how the guidelines can be used.

The guidelines do not evaluate the effect of unusual or special water constituents sometimes found in wastewater, such as pesticides and organics. However, suggested limits of trace element concentrations for normal irrigation water are given in section 5.5. As irrigation water

supplies frequently serve as a drinking water source for live-stock, salinity and trace element drinking water limitations for livestock are presented in section 6.

It is beyond the scope of this publication to go into drinking water standards, but this aspect should, nevertheless, be considered during the planning of an irrigation scheme. This is important, because irrigation supplies are also commonly used, either intentionally or unintentionally, as human drinking water. The World Health Organization (WHO) or a local health agency should be consulted for more specific information.

Laboratory determinations and calculations needed to use the guidelines are given in Table 2 and Figure 1, along with the symbols used. Analytical procedures for the laboratory determinations are given in several publications: USDA Handbook 60 (Richards 1954), Rhoades and Clark 1978, FAO Soils Bulletin 10 (Dewis and Freitas 1970), and Standard Methods for Examination of Waters and Wastewaters (APHA 1980). The method most appropriate for the available equipment, budget and number of samples should be used. Analytical accuracy within ±5 percent is considered adequate.

Table 1 GUIDELINES FOR INTERPRETATIONS OF WATER QUALITY FOR IRRIGATION[1]

Potential Irrigation Problem				Units	Degree of Restriction on Use		
					None	Slight to Moderate	Severe
Salinity *(affects crop water availability)*[2]							
	EC_w			dS/m	< 0.7	0.7 – 3.0	> 3.0
	(or)						
	TDS			mg/l	< 450	450 – 2000	> 2000
Infiltration *(affects infiltration rate of water into the soil. Evaluate using EC_w and SAR together)*[3]							
SAR	= 0 – 3	**and EC_w**	=		> 0.7	0.7 – 0.2	< 0.2
	= 3 – 6		=		> 1.2	1.2 – 0.3	< 0.3
	= 6 – 12		=		> 1.9	1.9 – 0.5	< 0.5
	= 12 – 20		=		> 2.9	2.9 – 1.3	< 1.3
	= 20 – 40		=		> 5.0	5.0 – 2.9	< 2.9
Specific Ion Toxicity *(affects sensitive crops)*							
	Sodium (Na)[4]						
	surface irrigation			SAR	< 3	3 – 9	> 9
	sprinkler irrigation			me/l	< 3	> 3	
	Chloride (Cl)[4]						
	surface irrigation			me/l	< 4	4 – 10	> 10
	sprinkler irrigation			me/l	< 3	> 3	
	Boron (B)[5]			mg/l	< 0.7	0.7 – 3.0	> 3.0
	Trace Elements (see Table 21)						
Miscellaneous Effects *(affects susceptible crops)*							
	Nitrogen (NO_3 - N)[6]			mg/l	< 5	5 – 30	> 30
	Bicarbonate (HCO_3)						
	(overhead sprinkling only)			me/l	< 1.5	1.5 – 8.5	> 8.5

	pH		**Normal Range 6.5 – 8.4**

[1] Adapted from University of California Committee of Consultants 1974.

[2] ECw means electrical conductivity, a measure of the water salinity, reported in deciSiemens per metre at 25°C (dS/m) or in units millimhos per centimetre (mmho/cm). Both are equiva-lent. TDS means total dissolved solids, reported in milligrams per litre (mg/l).

[3] SAR means sodium adsorption ratio. SAR is sometimes reported by the symbol RNa. See Figure1 for the SAR calculation procedure. At a given SAR, infiltration rate increases as watersalinity increases. Evaluate the potential infiltration problem by SAR as modified by ECw.Adapted from Rhoades 1977, and Oster and Schroer 1979.

[4] For surface irrigation, most tree crops and woody plants are sensitive to sodium and chlor-ide; use the values shown. Most annual crops are not sensitive; use the salinity tolerance tables (Tables 4 and 5). For chloride tolerance of selected fruit crops, see Table 14. With overhead sprinkler irrigation and low humidity (< 30 percent), sodium and chloride may be absorbed through the leaves of sensitive crops. For crop sensitivity to absorption, see Tables 18, 19 and 20.

[5] For boron tolerances, see Tables 16 and 17.

[6] NO_3 -N means nitrate nitrogen reported in terms of elemental nitrogen (NH_4 -N and Organic-N should be included when wastewater is being tested).

Assumptions in the Guidelines

The water quality guidelines in Table 1 are intended to cover the wide range of conditions encountered in irrigated agriculture. Several basic assumptions have been used to define their range of usability. If the water is used under greatly different conditions, the guidelines may need to be adjusted. Wide deviations from the assumptions might result in wrong judgements on the usability of a particular water supply, especially if it is a borderline case. Where sufficient experience, field trials, research or observations are available, the guidelines may be modified to fit local conditions more closely.

The basic assumptions in the guidelines are:

Yield Potential: Full production capability of all crops, without the use of special practices, is assumed when the guidelines indicate no restrictions on use. A "restriction on use" indicates that there may be a limitation in choice of crop, or special management may be needed to maintain full production capability. A "restriction on use" does not indicate that the water is unsuitable for use.

Site Conditions: Soil texture ranges from sandy-loam to clay-loam with good internal drainage. The climate is semi-arid to arid and rainfall is low. Rainfall does not play a significant role in meeting crop water demand or leaching requirement. (In a monsoon climate or areas where precipitation is high for part or all of the year, the guideline restrictions are too severe. Under the higher rainfall situations, infiltrated water from rainfall is effective in meeting all or part of the leaching requirement.) Drainage is assumed to be good, with no uncontrolled shallow water table present within 2 metres of the surface.

Methods and Timing of Irrigations: Normal surface or sprinkler irrigation methods are used. Water is applied infrequently, as needed, and the crop utilizes a considerable portion of the available stored soil-water (50 percent or more) before the next irrigation. At least 15 percent of the applied water percolates below the root zone (leaching fraction [LF]≥15 percent). The guidelines are too restrictive for specialized irrigation methods, such as localized drip irrigation, which results in near daily or frequent irrigations, but are applicable for subsurface irrigation if surface applied leaching satisfies the leaching requirements.

Water Uptake by Crops: Different crops have different water uptake patterns, but all take water from wherever it is most readily available within the rooting depth. On average about 40 percent is assumed to be taken from the upper quarter of the rooting depth, 30 percent from the second quarter, 20 percent from the third quarter, and 10 percent from the lowest quarter. Each irrigation leaches the upper root zone and maintains it at a relatively low salinity. Salinity increases with depth and is greatest in the lower part of the root zone. The average salinity of the soil-water is three times that of the applied water and is representative of the average root zone salinity to which the crop responds. These conditions result from a leaching fraction of 15–20 percent and irrigations that are timed to keep the crop adequately watered at all times.

Salts leached from the upper root zone accumulate to some extent in the lower part but a salt balance is achieved as salts are moved below the root zone by sufficient leaching. The higher salinity in the lower root zone becomes less important if adequate moisture is maintained in the upper, "more active" part of the root zone and long-term leaching is accomplished.

Restriction on Use: The "Restriction on Use" shown in Table 1 is divided into three degree of severity: none, slight to moderate, and severe. The divisions are somewhat arbitrary since change occurs gradually and there is no clearcut breaking point. A change of 10 to 20 percent above or below a guideline value has little significance if considered in proper perspective with other factors affecting yield. Field studies, research trials and observations have led to these divisions, but management skill of the water user can alter them. Values shown are applicable under normal field conditions prevailing in most irrigated areas in the arid and semi-arid regions of the world.

Table 2 LABORATORY DETERMINATIONS NEEDED TO EVALUATE COMMON IRRIGATION WATER QUALITY PROBLEMS

Water parameter	Symbol	Unit[1]	Usual range in irrigation water	
SALINITY				
Salt Content				
Electrical Conductivity	EC_w	dS/m	0 – 3	dS/m
(or)				
Total Dissolved Solids	TDS	mg/l	0 – 2000	mg/l
Cations and Anions				
Calcium	Ca^{++}	me/l	0 – 20	me/l
Magnesium	Mg^{++}	me/l	0 – 5	me/l
Sodium	Na^{+}	me/l	0 – 40	me/l
Carbonate	CO^{--}_3	me/l	0 – .1	me/l
Bicarbonate	HCO_3^-	me/l	0 – 10	me/l
Chloride	Cl^-	me/l	0 – 30	me/l
Sulphate	SO_4^{--}	me/l	0 – 20	me/l
NUTRIENTS[2]				
Nitrate-Nitrogen	NO_3-N	mg/l	0 – 10	mg/l
Ammonium-Nitrogen	NH_4-N	mg/l	0 – 5	mg/l
Phosphate-Phosphorus	PO_4-P	mg/l	0 – 2	mg/l
Potassium	K^+	mg/l	0 – 2	mg/l
MISCELLANEOUS				
Boron	B	mg/l	0 – 2	mg/l
Acid/Basicity	pH	1–14	6.0 – 8.5	
Sodium Adsorption Ratio[3]	SAR	(me/l)[1, 2]	0 – 15	

[1] dS/m = deciSiemen/metre in S.I. units (equivalent to 1 mmho/cm = 1 millimmho/centi-metre)

mg/l = milligram per litre ≃ parts per million (ppm).

me/l = milliequivalent per litre (mg/l ÷ equivalent weight = me/l); in SI units, 1 me/l= 1 millimol/litre adjusted for electron charge.

[2] NO_3 -N means the laboratory will analyse for NO_3 but will report the NO_3 in terms of chemically equivalent nitrogen. Similarly, for NH_4-N, the laboratory will analyse for NH_4 but report in terms of chemically equivalent elemental nitrogen. The total nitrogen available to the plant will be the sum of the equivalent elemental nitrogen.The same reporting method is used for phosphorus.

[3] SAR is calculated from the Na, Ca and Mg reported in me/l (see Figure 1).

The Sodium Adsorption Ratio (SAR) can also be calculated using the following equation:

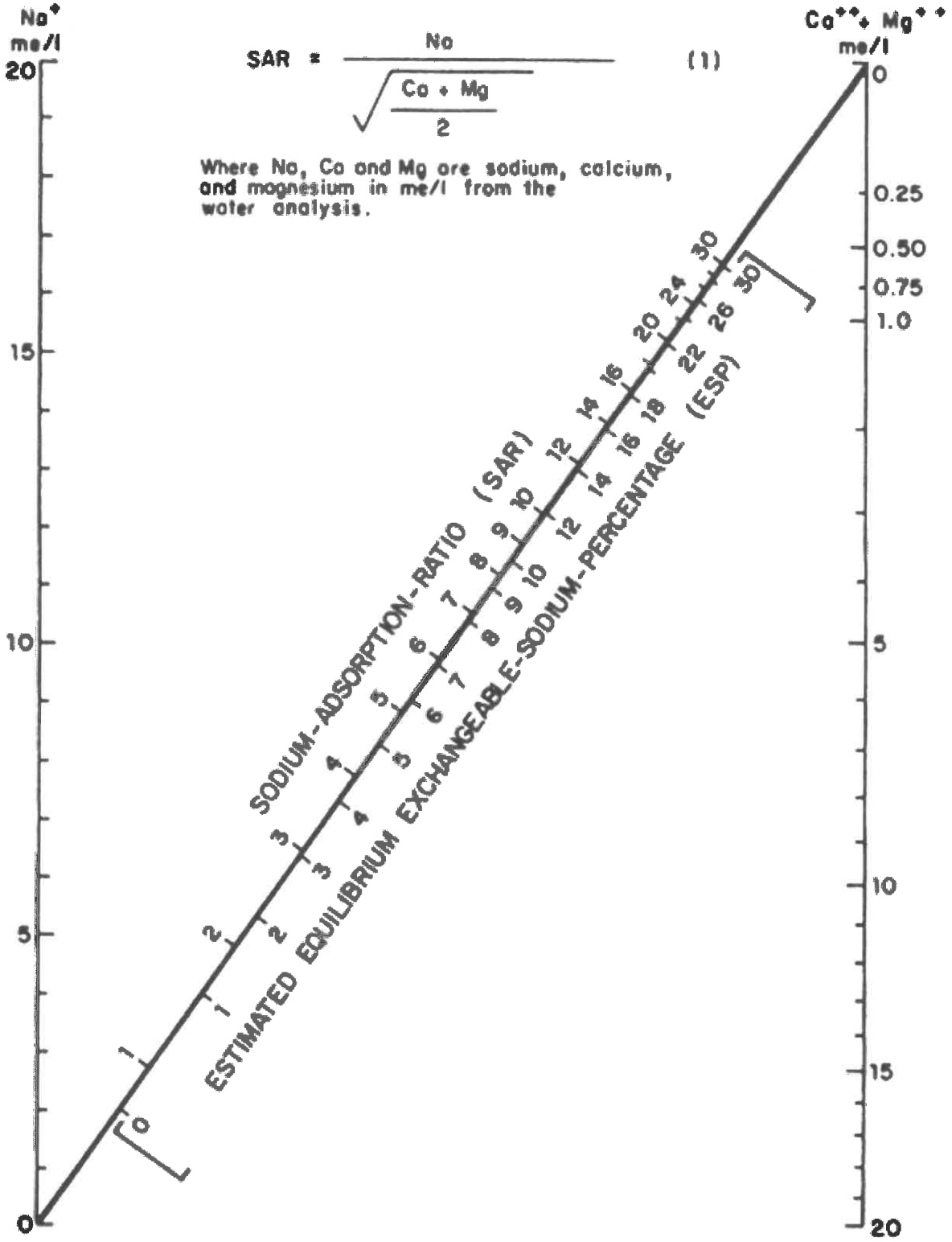


Fig. 1 Nomogram for determining the SAR value of irrigation water and for estimating the corresponding ESP value of a soil that is at equilibrium with the water (Richards 1954)

1. WATER QUALITY EVALUATION

1.1 INTRODUCTION

Irrigated agriculture is dependent on an adequate water supply of usable quality. Water quality concerns have often been neglected because good quality water supplies have been plentigul and readily available. This situation is now changing in many areas. Intensive use of nearly all good quality supplies means that new irrigation projects and old projects seeking new or supplemental supplies must rely on lower quality and less desirable sources. To avoid problems when using these poor quality water supplies, there must be sound planning to ensure that the quality of water available is put to the best use.

The objective of this paper is to help the reader to a better understanding of the effect of water quality upon soil and crops and to assist in selecting suitable alternatives to cope with potential water quality related problems that might reduce production under prevailing conditions of use.

Conceptually, water quality refers to the characteristics of a water supply that will influence its suitability for a specific use, i.e. how well the quality meets the needs of the user. Quality is defined by certain physical, chemical and biological characteristics. Even a personal preference such as taste is a simple evaluation of acceptability. For example, if two drinking waters of equally good quality are available, people may express a preference for one supply rather than the other; the better tasting water becomes the preferred supply. In irrigation water evaluation, emphasis is placed on the chemical and physical characteristics of the water and only rarely are any other factors considered important.

Specific uses have different quality needs and one water supply is considered more acceptable (of better quality) if it produces better results or causes fewer problems than an alternative water supply. For example, good quality river water which can be used successfully for irrigation may, because of its sediment load, be unacceptable for municipal use without treatment to remove the sediment. Similarly, snowmelt water of excellent quality for municipal use may be too corrosive for industrial use without treatment to reduce its corrosion potential.

The ideal situation is to have several supplies from which to make a selection, but normally only one supply is available. In this case, the quality of the available supply must be evaluated to see how it fits the intended use. Most of the experience in using water of different qualities has been gained from observations and detailed study of problems that develop following use. The cause and effect relationship between a water constituent and the observed problem then results in an evaluation of quality of degree of acceptability. With sufficient reported experiences and measured responses, certain constituents emerge as indicators of quality-related problems. These characteristics are then organized into guidelines related to suitability for use. Each new set of guidelines builds upon the previous set to improve the predictive capability. Numerous such guidelines have become available covering many types of use.

There have been a number of different water quality guidelines related to irrigated agriculture. Each has been useful but none has been entirely satisfactory because of the wide variability in field conditions. Hopefully, each new set of guidelines has improved our predictive capability. The guidelines presented in this paper have relied heavily on previous ones but are modified to give more practical procedures for evaluating and managing water quality-related problems of

irrigated agriculture. They are an updated version of those in the 1976 edition of this paper. Changes from the 1976 edition are discussed in the appropriate sections of the paper.

1.2 WATER QUALITY PROBLEMS

Water used for irrigation can vary greatly in quality depending upon type and quantity of dissolved salts. Salts are present in irrigation water in relatively small but significant amounts. They originate from dissolution or weathering of the rocks and soil, including dissolution of lime, gypsum and other slowly dissolved soil minerals. These salts are carried with the water to wherever it is used. In the case of irrigation, the salts are applied with the water and remain behind in the soil as water evaporates or is used by the crop.

The suitability of a water for irrigation is determined not only by the total amount of salt present but also by the kind of salt. Various soil and cropping problems develop as the total salt content increases, and special management practices may be required to maintain acceptable crop yields. Water quality or suitability for use is judged on the potential severity of problems that can be expected to develop during long-term use.

The problems that result vary both in kind and degree, and are modified by soil, climate and crop, as well as by the skill and knowledge of the water user. As a result, there is no set limit on water quality; rather, its suitability for use is determined by the conditions of use which affect the accumulation of the water constituents and which may restrict crop yield. The soil problems most commonly encountered and used as a basis to evaluate water quality are those related to salinity, water infiltration rate, toxicity and a group of other miscellaneous problems.

WATER QUALITY-RELATED PROBLEMS IN IRRIGATED AGRICULTURE

SALINITY

Salts in soil or water reduce water availability to the crop to such an extent that yield is affected.

WATER INFILTRATION RATE

Relatively high sodium or low calcium content of soil or water reduces the rate at which irrigation water enters soil to such an extent that sufficient water cannot be infiltrated to supply the crop adequately from one irrigation to the next.

SPECIFIC ION TOXICITY

Certain ions (sodium, chloride, or boron) from soil or water accumulate in a sensitive crop to concentrations high enough to cause crop damage and reduce yields.

MISCELLANEOUS

Excessive nutrients reduce yield or quality; unsightly deposits on fruit or foliage reduce marketability; excessive corrosion of equipment increases maintenance and repairs.

1.2.1 Salinity

A salinity problem exists if salt accumulates in the crop root zone to a concentration that causes a loss in yield. In irrigated areas, these salts often originate from a saline, high water table or from salts in the applied water. Yield reductions occur when the salts accumulate in the root zone to such an extent that the crop is no longer able to extract sufficient water from the salty soil solution, resulting in a water stress for a significant period of time. If water uptake is

appreciably reduced, the plant slows its rate of growth. The plant symptoms are similar in appearance to those of drought, such as wilting, or a darker, bluish-green colour and sometimes thicker, waxier leaves. Symptoms vary with the growth stage, being more noticeable if the salts affect the plant during the early stages of growth. In some cases, mild salt effects may go entirely unnoticed because of a uniform reduction in growth across an entire field.

Salts that contribute to a salinity problem are water soluble and readily transported by water. A portion of the salts that accumulate from prior irrigations can be moved (leached) below the rooting depth if more irrigation water infiltrates the soil than is used by the crop during the crop season. Leaching is the key to controlling a water quality-related salinity problem. Over a period of time, salt removal by leaching must equal or exceed the salt additions from the applied water to prevent salt building up to a damaging concentration. The amount of leaching required is dependent upon the irrigation water quality and the salinity tolerance of the crop grown.

Salt content of the root zone varies with depth. It varies from approximately that of the irrigation water near the soil surface to many times that of the applied water at the bottom of the rooting depth. Salt concentration increases with depth due to plants extracting water but leaving salts behind in a greatly reduced volume of soil water. Each subsequent irrigation pushes (leaches) the salts deeper into the root zone where they continue to accumulate until leached. The lower rooting depth salinity will depend upon the leaching that has occurred.

Following an irrigation, the most readily available water is in the upper root zone - a low salinity area. As the crop uses water, the upper root zone becomes depleted and the zone of most readily available water changes toward the deeper parts as the time interval between irrigations is extended. These lower depths are usually more salty. The crop does not respond to the extremes of low or high salinity in the rooting depth but integrates water availability and takes water from wherever it is most readily available. Irrigation timing is thus important in maintaining a high soil-water availability and reducing the problems caused when the crop must draw a significant portion of its water from the less available, higher salinity soil-water deeper in the root zone. For good crop production, equal importance must be given to maintaining a high soil-water availability and to leaching accumulated salts from the rooting depth before the salt concentration exceeds the tolerance of the plant.

For crops irrigated infrequently, as is normal when using surface methods and conventional irrigation management, crop yield is best correlated with the average root zone salinity, but for crops irrigated on a daily, or near daily basis (localized or drip irrigation) crop yields are better correlated with the water-uptake weighted root zone salinity (Rhoades 1982). The differences are not great but may become important in the higher range of salinity. In this paper, discussions are based on crop response to the average root zone salinity.

In irrigated agriculture, many salinity problems are associated with or strongly influenced by a shallow water table (within 2 metres of the surface). Salts accumulate in this water table and frequently become an important additional source of salt that moves upward into the crop root zone. Control of an existing shallow water table is thus essential to salinity control and to successful long-term irrigated agriculture. Higher salinity water requires appreciable extra water for leaching, which adds greatly to a potential water table (drainage) problem and makes long-term irrigated agriculture nearly impossible to achieve without adequate drainage. If drainage is adequate, salinity control becomes simply good management to ensure that the crop is adequately supplied with water at all times and that enough leaching water is applied to control salts within the tolerance of the crop.

1.2.2 Water Infiltration Rate

An infiltration problem related to water quality occurs when the normal infiltration rate for the applied water or rainfall is appreciably reduced and water remains on the soil surface too long or infiltrates too slowly to supply the crop with sufficient water to maintain acceptable yields. Although the infiltration rate of water into soil varies widely and can be greatly influenced by the quality of the irrigation water, soil factors such as structure, degree of compaction, organic matter content and chemical make-up can also greatly influence the intake rate.

The two most common water quality factors which influence the normal infiltration rate are the salinity of the water (total quantity of salts in the water) and its sodium content relative to the calcium and magnesium content. A high salinity water will increase infiltration. A low salinity water or a water with a high sodium to calcium ratio will decrease infiltration. Both factors may operate at the same time. Secondary problems may also develop if irrigations must be prolonged for an extended period of time to achieve adequate infiltration. These include crusting of seedbeds, excessive weeds, nutritional disorders and drowning of the crop, rotting of seeds and poor crop stands in low-lying wet spots. One serious side effect of an infiltration problem is the potential to develop disease and vector (mosquito) problems.

An infiltration problem related to water quality in most cases occurs in the surface few centimetres of soil and is linked to the structural stability of this surface soil and its low calcium content relative to that of sodium. When a soil is irrigated with a high sodium water, a high sodium surface soil develops which weakens soil structure. The surface soil aggregates then disperse to much smaller particles which clog soil pores. The problem may also be caused by an extremely low calcium content of the surface soil. In some cases, water low in salt can cause a similar problem but this is related to the corrosive nature of the low salt water and not to the sodium content of the water or soil. In the case of the low salt water, the water dissolves and leaches most of the soluble minerals, including calcium, from the surface soil.

1.2.3 Toxicity

Toxicity problems occur if certain constituents (ions) in the soil or water are taken up by the plant and accumulate to concentrations high enough to cause crop damage or reduced yields. The degree of damage depends on the uptake and the crop sensitivity. The permanent, perennial-type crops (tree crops) are the more sensitive. Damage often occurs at relatively low ion concentrations for sensitive crops. It is usually first evidenced by marginal leaf burn and interveinal chlorosis. If the accumulation is great enough, reduced yields result. The more tolerant annual crops are not sensitive at low concentrations but almost all crops will be damaged or killed if concentrations are sufficiently high.

The ions of primary concern are chloride, sodium and boron. Although toxicity problems may occur even when these ions are in low concentrations, toxicity often accompanies and complicates a salinity or water infiltration problem. Damage results when the potentially toxic ions are absorbed in significant amounts with the water taken up by the roots. The absorbed ions are transported to the leaves where they accumulate during transpiration. The ions accumulate to the greatest extent in the areas where the water loss is greatest, usually the leaf tips and leaf edges. Accumulation to toxic concentrations takes time and visual damage is often slow to be noticed. The degree of damage depends upon the duration of exposure, concentration by the toxic ion, crop sensitivity, and the volume of water transpired by the crop. In a hot climate or hot part of the year, accumulation is more rapid than if the same crop were grown in a cooler climate or cooler season when it might show little or no damage.

Toxicity can also occur from direct absorption of the toxic ions through leaves wet by overhead sprinklers. Sodium and chloride are the primary ions absorbed through leaves, and toxicity to

one or both can be a problem with certain sensitive crops such as citrus. As concentrations increase in the applied water, damage develops more rapidly and becomes progressively more severe.

1.2.4 Miscellaneous

Several other problems related to irrigation water quality occur with sufficient frequency for them to be specifically noted. These include high nitrogen concentrations in the water which supplies nitrogen to the crop and may cause excessive vegetative growth, lodging, and delayed crop maturity; unsightly deposits on fruit or leaves due to overhead sprinkler irrigation with high bicarbonate water, water containing gypsum, or water high in iron; and various abnormalities often associated with an unusual pH of the water. A special problem faced by some farmers practising irrigation is deterioration of equipment due to water-induced corrosion or encrustation. This problem is most serious for wells and pumps, but in some areas, a poor quality water may also damage irrigation equipment and canals. In areas where there is a potential risk from diseases such as malaria, schistosomiasis and lymphatic filariasis, disease vector problems must be considered along with other water quality-related problems. Vector problems (mosquitoes) often originate as a secondary trouble related to a low water infiltration rate, to the use of wastewater for irrigation, or to poor drainage. Suspended organic as well as inorganic sediments cause problems in irrigation systems through clogging of gates, sprinkler heads and drippers. They can cause damage to pumps if screens are not used to exclude them. More commonly, sediments tend to fill canals and ditches and cause costly dredging and maintenance problems. Sediment also tends to reduce further the water infiltration rate of an already slowly permeable soil.

1.3 APPROACH TO EVALUATING WATER QUALITY

The prediction that a water quality-related problem will occur requires evaluation of the potential of the water to create soil conditions that may restrict its use or that may require the use of special management techniques to maintain acceptable yields. There are a number of procedures available for this evaluation but regardless of which one is used, emphasis should focus on relating the potential problem to the field situation since solutions to water quality problems usually must be implemented at the farm level rather than at the project level. The evaluation must therefore be done in terms of specific local conditions of use and the farm management capability of the water user.

This approach is the same as in the 1976 edition of this paper and similar guidelines are proposed for evaluating the potential of an irrigation water to create soil or crop problems. The guidelines are followed by suggestions on management alternatives to overcome these potential problems. This approach is often referred to as a problem-solving approach and emphasizes long-term effects on irrigated agriculture rather than short-term, because of the large investments now needed in irrigated agriculture.

The four problem categories previously discussed - **salinity, infiltration, toxicity** and **miscellaneous** - are used for evaluation. Water quality problems, however, are often complex and a combination of problems may affect crop production more severely than a single problem in isolation. The more complex the problem, the more difficult it is to formulate an economical management programme for solution.

If problems do occur in combination, they are more easily understood and solved if each factor is considered individually. Therefore, the guidelines and discussion which follow treat each problem and its solution separately, so that a number of factors are evaluated for each of the problem areas, such as:

- the type and concentration of salts causing the problem;
- the soil-water-plant interactions that may cause the loss in crop yield;
- the expected severity of the problem following long-term use of the water;
- the management options that are available to prevent, correct, or delay the onset of the problem.

1.4 WATER QUALITY GUIDELINES

Guidelines for evaluation of water quality for irrigation are given in Table 1. They emphasize the long-term influence of water quality on crop production, soil conditions and farm management, and are presented in the same format as in the 1976 edition but are updated to include recent research results. This format is similar to that of the 1974 University of California Committee of Consultant's Water Quality Guidelines which were prepared in cooperation with staff of the United States Salinity Laboratory.

The guidelines are practical and have been used successfully in general irrigated agriculture for evaluation of the common constituents in surface water, groundwater, drainage water, sewage effluent and wastewater. They are based on certain assumptions which are given immediately following the table. These assumptions must be clearly understood but should not become rigid prerequisites. A modified set of alternative guidelines can be prepared if actual conditions of use differ greatly from those assumed.

Ordinarily, no soil or cropping problems are experienced or recognized when using water with values less than those shown for 'no restriction on use'. With restrictions in the slight to moderate range, gradually increasing care in selection of crop and management alternatives is required if full yield potential is to be achieved. On the other hand, if water is used which equals or exceeds the values shown for severe restrictions, the water user should experience soil and cropping problems or reduced yields, but even with cropping management designed especially to cope with poor quality water, a high level of management skill is essential for acceptable production. If water quality values are found which approach or exceed those given for the severe restriction category, it is recommended that before initiating the use of the water in a large project, a series of pilot farming studies be conducted to determine the economics of the farming and cropping techniques that need to be implemented.

Table 1 is a management tool. As with many such interpretative tools in agriculture, it is developed to help users such as water agencies, project planners, agriculturalists, scientists and trained field people to understand better the effect of water quality on soil conditions and crop production. With this understanding, the user should be able to adjust management to utilize poor quality water better. However, the user of Table 1 must guard against drawing unwarranted conclusions based only on the laboratory results and the guideline interpretations as these must be related to field conditions and must be checked, confirmed and tested by field trials or experience.

The guidelines are a first step in pointing out the quality limitations of a water supply, but this alone is not enough; methods to overcome or adapt to them are also needed. Therefore, in subsequent sections, management alternatives are presented and several examples are given to illustrate how the guidelines can be used.

The guidelines do not evaluate the effect of unusual or special water constituents sometimes found in wastewater, such as pesticides and organics. However, suggested limits of trace element concentrations for normal irrigation water are given in section 5.5. As irrigation water

supplies frequently serve as a drinking water source for live-stock, salinity and trace element drinking water limitations for livestock are presented in section 6.

It is beyond the scope of this publication to go into drinking water standards, but this aspect should, nevertheless, be considered during the planning of an irrigation scheme. This is important, because irrigation supplies are also commonly used, either intentionally or unintentionally, as human drinking water. The World Health Organization (WHO) or a local health agency should be consulted for more specific information.

Laboratory determinations and calculations needed to use the guidelines are given in Table 2 and Figure 1, along with the symbols used. Analytical procedures for the laboratory determinations are given in several publications: USDA Handbook 60 (Richards 1954), Rhoades and Clark 1978, FAO Soils Bulletin 10 (Dewis and Freitas 1970), and Standard Methods for Examination of Waters and Wastewaters (APHA 1980). The method most appropriate for the available equipment, budget and number of samples should be used. Analytical accuracy within ±5 percent is considered adequate.

Table 1 GUIDELINES FOR INTERPRETATIONS OF WATER QUALITY FOR IRRIGATION[1]

Potential Irrigation Problem				Units	Degree of Restriction on Use		
					None	Slight to Moderate	Severe
Salinity *(affects crop water availability)*[2]							
	EC_w			dS/m	< 0.7	0.7 – 3.0	> 3.0
	(or)						
	TDS			mg/l	< 450	450 – 2000	> 2000
Infiltration *(affects infiltration rate of water into the soil. Evaluate using EC_w and SAR together)*[3]							
SAR	= 0 – 3	**and EC_w**	=		> 0.7	0.7 – 0.2	< 0.2
	= 3 – 6		=		> 1.2	1.2 – 0.3	< 0.3
	= 6 – 12		=		> 1.9	1.9 – 0.5	< 0.5
	= 12 – 20		=		> 2.9	2.9 – 1.3	< 1.3
	= 20 – 40		=		> 5.0	5.0 – 2.9	< 2.9
Specific Ion Toxicity *(affects sensitive crops)*							
	Sodium (Na)[4]						
	surface irrigation			SAR	< 3	3 – 9	> 9
	sprinkler irrigation			me/l	< 3	> 3	
	Chloride (Cl)[4]						
	surface irrigation			me/l	< 4	4 – 10	> 10
	sprinkler irrigation			me/l	< 3	> 3	
	Boron (B)[5]			mg/l	< 0.7	0.7 – 3.0	> 3.0
	Trace Elements (see Table 21)						
Miscellaneous Effects *(affects susceptible crops)*							
	Nitrogen (NO_3 - N)[6]			mg/l	< 5	5 – 30	> 30
	Bicarbonate (HCO_3)						
	(overhead sprinkling only)			me/l	< 1.5	1.5 – 8.5	> 8.5

	pH		**Normal Range 6.5 – 8.4**

[1] Adapted from University of California Committee of Consultants 1974.

[2] ECw means electrical conductivity, a measure of the water salinity, reported in deciSiemens per metre at 25°C (dS/m) or in units millimhos per centimetre (mmho/cm). Both are equiva-lent. TDS means total dissolved solids, reported in milligrams per litre (mg/l).

[3] SAR means sodium adsorption ratio. SAR is sometimes reported by the symbol RNa. See Figure1 for the SAR calculation procedure. At a given SAR, infiltration rate increases as watersalinity increases. Evaluate the potential infiltration problem by SAR as modified by ECw.Adapted from Rhoades 1977, and Oster and Schroer 1979.

[4] For surface irrigation, most tree crops and woody plants are sensitive to sodium and chlor-ide; use the values shown. Most annual crops are not sensitive; use the salinity tolerance tables (Tables 4 and 5). For chloride tolerance of selected fruit crops, see Table 14. With overhead sprinkler irrigation and low humidity (< 30 percent), sodium and chloride may be absorbed through the leaves of sensitive crops. For crop sensitivity to absorption, see Tables 18, 19 and 20.

[5] For boron tolerances, see Tables 16 and 17.

[6] NO_3 -N means nitrate nitrogen reported in terms of elemental nitrogen (NH_4 -N and Organic-N should be included when wastewater is being tested).

Assumptions in the Guidelines

The water quality guidelines in Table 1 are intended to cover the wide range of conditions encountered in irrigated agriculture. Several basic assumptions have been used to define their range of usability. If the water is used under greatly different conditions, the guidelines may need to be adjusted. Wide deviations from the assumptions might result in wrong judgements on the usability of a particular water supply, especially if it is a borderline case. Where sufficient experience, field trials, research or observations are available, the guidelines may be modified to fit local conditions more closely.

The basic assumptions in the guidelines are:

Yield Potential: Full production capability of all crops, without the use of special practices, is assumed when the guidelines indicate no restrictions on use. A "restriction on use" indicates that there may be a limitation in choice of crop, or special management may be needed to maintain full production capability. A "restriction on use" does not indicate that the water is unsuitable for use.

Site Conditions: Soil texture ranges from sandy-loam to clay-loam with good internal drainage. The climate is semi-arid to arid and rainfall is low. Rainfall does not play a significant role in meeting crop water demand or leaching requirement. (In a monsoon climate or areas where precipitation is high for part or all of the year, the guideline restrictions are too severe. Under the higher rainfall situations, infiltrated water from rainfall is effective in meeting all or part of the leaching requirement.) Drainage is assumed to be good, with no uncontrolled shallow water table present within 2 metres of the surface.

Methods and Timing of Irrigations: Normal surface or sprinkler irrigation methods are used. Water is applied infrequently, as needed, and the crop utilizes a considerable portion of the available stored soil-water (50 percent or more) before the next irrigation. At least 15 percent of the applied water percolates below the root zone (leaching fraction [LF]≥15 percent). The guidelines are too restrictive for specialized irrigation methods, such as localized drip irrigation, which results in near daily or frequent irrigations, but are applicable for subsurface irrigation if surface applied leaching satisfies the leaching requirements.

Water Uptake by Crops: Different crops have different water uptake patterns, but all take water from wherever it is most readily available within the rooting depth. On average about 40 percent is assumed to be taken from the upper quarter of the rooting depth, 30 percent from the second quarter, 20 percent from the third quarter, and 10 percent from the lowest quarter. Each irrigation leaches the upper root zone and maintains it at a relatively low salinity. Salinity increases with depth and is greatest in the lower part of the root zone. The average salinity of the soil-water is three times that of the applied water and is representative of the average root zone salinity to which the crop responds. These conditions result from a leaching fraction of 15–20 percent and irrigations that are timed to keep the crop adequately watered at all times.

Salts leached from the upper root zone accumulate to some extent in the lower part but a salt balance is achieved as salts are moved below the root zone by sufficient leaching. The higher salinity in the lower root zone becomes less important if adequate moisture is maintained in the upper, "more active" part of the root zone and long-term leaching is accomplished.

Restriction on Use: The "Restriction on Use" shown in Table 1 is divided into three degree of severity: none, slight to moderate, and severe. The divisions are somewhat arbitrary since change occurs gradually and there is no clearcut breaking point. A change of 10 to 20 percent above or below a guideline value has little significance if considered in proper perspective with other factors affecting yield. Field studies, research trials and observations have led to these divisions, but management skill of the water user can alter them. Values shown are applicable under normal field conditions prevailing in most irrigated areas in the arid and semi-arid regions of the world.

Table 2 LABORATORY DETERMINATIONS NEEDED TO EVALUATE COMMON IRRIGATION WATER QUALITY PROBLEMS

Water parameter	Symbol	Unit[1]	Usual range in irrigation water	
SALINITY				
Salt Content				
Electrical Conductivity	EC_w	dS/m	0 – 3	dS/m
(or)				
Total Dissolved Solids	TDS	mg/l	0 – 2000	mg/l
Cations and Anions				
Calcium	Ca^{++}	me/l	0 – 20	me/l
Magnesium	Mg^{++}	me/l	0 – 5	me/l
Sodium	Na^{+}	me/l	0 – 40	me/l
Carbonate	CO^{--}_3	me/l	0 – .1	me/l
Bicarbonate	HCO_3^-	me/l	0 – 10	me/l
Chloride	Cl^-	me/l	0 – 30	me/l
Sulphate	SO_4^{--}	me/l	0 – 20	me/l
NUTRIENTS[2]				
Nitrate-Nitrogen	NO_3-N	mg/l	0 – 10	mg/l
Ammonium-Nitrogen	NH_4-N	mg/l	0 – 5	mg/l
Phosphate-Phosphorus	PO_4-P	mg/l	0 – 2	mg/l
Potassium	K^+	mg/l	0 – 2	mg/l
MISCELLANEOUS				
Boron	B	mg/l	0 – 2	mg/l
Acid/Basicity	pH	1–14	6.0 – 8.5	
Sodium Adsorption Ratio[3]	SAR	(me/l)[1, 2]	0 – 15	

[1] dS/m = deciSiemen/metre in S.I. units (equivalent to 1 mmho/cm = 1 millimmho/centi-metre)

mg/l = milligram per litre ≃ parts per million (ppm).

me/l = milliequivalent per litre (mg/l ÷ equivalent weight = me/l); in SI units, 1 me/l= 1 millimol/litre adjusted for electron charge.

[2] NO_3 -N means the laboratory will analyse for NO_3 but will report the NO_3 in terms of chemically equivalent nitrogen. Similarly, for NH_4-N, the laboratory will analyse for NH_4 but report in terms of chemically equivalent elemental nitrogen. The total nitrogen available to the plant will be the sum of the equivalent elemental nitrogen.The same reporting method is used for phosphorus.

[3] SAR is calculated from the Na, Ca and Mg reported in me/l (see Figure 1).

The Sodium Adsorption Ratio (SAR) can also be calculated using the following equation:

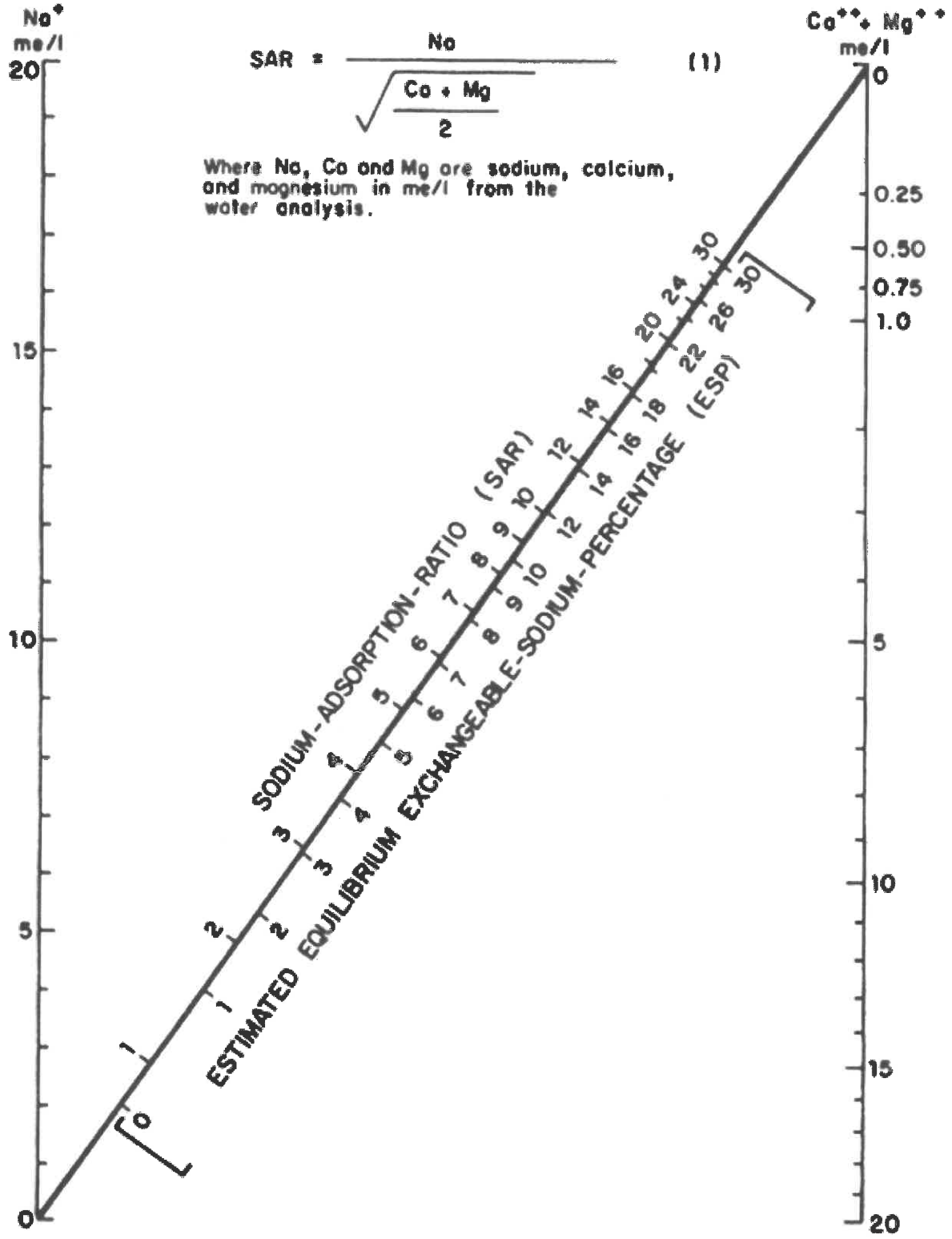


Fig. 1 Nomogram for determining the SAR value of irrigation water and for estimating the corresponding ESP value of a soil that is at equilibrium with the water (Richards 1954)

2. SALINITY PROBLEMS

2.1 INTRODUCTION

Irrigation water contains a mixture of naturally occurring salts. Soils irrigated with this water will contain a similar mix but usually at a higher concentration than in the applied water. The extent to which the salts accumulate in the soil will depend upon the irrigation water quality, irrigation management and the adequacy of drainage. If salts become excessive, losses in yield will result. To prevent yield loss, salts in the soil must be controlled at a concentration below that which might affect yield.

Most water used for irrigation is of good to excellent quality and is unlikely to present serious salinity constraints. Salinity control, however, becomes more difficult as water quality becomes poorer. As water salinity increases, greater care must be taken to leach salts out of the root zone before their accumulation reaches a concentration which might affect yields. Alternatively, steps must be taken to plant crops tolerant to the expected root zone salinity. The frequency of leaching depends on water quality and the crop sensitivity to salinity.

The intent of this chapter is to illustrate the effect of water quality on the build-up of soil salinity and show how the latter can reduce the soil-water available to the crop. This is followed by a discussion of how leaching, crop selection and other management techniques are used to make salinity control easier and allow greater use of more saline water in irrigated agriculture. Emphasis will be on how to manage intermediate quality water with slight to moderate restrictions on use, as shown in Table 1. Such water could result in more severe problems if it is not properly managed. The same management techniques will apply to a poorer quality water, but as quality worsens the options for management become fewer.

2.2 BUILD-UP OF SOIL SALINITY

Salts are added to the soil with each irrigation. These salts will reduce crop yield if they accumulate in the rooting depth to damaging concentrations. The crop removes much of the applied water from the soil to meet its evapotranspiration demand (ET) but leaves most of the salt behind to concentrate in the shrinking volume of soilwater. At each irrigation, more salt is added with the applied water. A portion of the added salt must be leached from the root zone before the concentration affects crop yield. Leaching is done by applying sufficient water so that a portion percolates through and below the entire root zone carrying with it a portion of the accumulated salts. The fraction of applied water that passes through the entire rooting depth and percolates below is called the leaching fraction (LF).

$$\text{Leaching Fraction (LF)} = \frac{\text{depth of water leached below the root zone}}{\text{depth of water applied at the surface}} \quad (2)$$

After many successive irrigations, the salt accumulation in the soil will approach some equilibrium concentration based on the salinity of the applied water and the leaching fraction. A high leaching fraction (LF = 0.5) results in less salt accumulation than a lower leaching fraction (LF = 0.1). If the water salinity (ECw) and the leaching fraction (LF) are known or can be estimated, both the salinity of the drainage water that percolates below the rooting depth and

the average root zone salinity can be estimated. The salinity of the drainage water can be estimated from the equation:

$$EC_{dw} = \frac{EC_w}{LF} \qquad (3)$$

where: EC_{dw} = salinity of the drainage water percolating below the root zone (equal to salinity of soil-water, EC_{sw})

EC_w = salinity of the applied irrigation water

LF = leaching fraction

In Example 1, the leaching fraction and water quality are used to predict drainage water quality. The plant, however, is only exposed to this drainage water salinity at the lowest part of the root zone. The salinity in this lower portion of the root zone tends to be higher than in the upper portion due to its much lower leaching fraction. The crop responds, however, to the average root zone soil salinity and not to the extremes of either the upper or lower zones.

EXAMPLE 1 - CALCULATION OF CONCENTRATION OF DEEP PERCOLATION FROM THE BOTTOM OF THE ROOT ZONE

A crop is irrigated with water of an electrical conductivity (ECw) of 1 dS/m. The crop is irrigated to achieve a leaching fraction of 0.15 (assumes that 85 percent of the applied water is used by the crop or evaporates from the soil surface).

Given: EC_w = 1 dS/m

LF = 0.15

Explanation:

The concentration of the soil-water percolating below the root zone (ECsw) is equivalent to the concentration of the drainage water (ECdw) accumulating below the root zone. The salinity of the deep percolation from the bottom of the root zone (drainage water) can be estimated by using equation (3):

$$EC_{dw} = EC_{sw} = \frac{EC_w}{LF} \qquad (3)$$

$$EC_{dw} = \frac{1}{0.15} = 6.7 \text{ dS/m}$$

The salinity of the soil-water that is percolating from the bottom of the root zone (EC_{dw}) will be approximately 6.7 dS/m.

Equation (3) can also be used to predict average soil-water salinity (ECsw) in the rooting depth if certain assumptions are made regarding water use within the root zone. The guidelines of Table 1 assume that 40, 30, 20 and 10 percent of the water used by the crop comes, respectively, from the upper to lower quarter of the rooting depth. This water use pattern closely fits conditions found under normal irrigation practices. An illustration is given in Example 2 where the above water use pattern is used to estimate average soil-water salinity (ECsw).

Example 2 shows that with a 15 percent leaching fraction and a 40-30-20-10 water use pattern the average soil-water salinity (ECsw) is approximately 3.2 times more concentrated than the applied irrigation water. At a leaching fraction of 20 percent, the average ECsw is 2.7 times the

salinity of the applied irrigation water (ECw). The guidelines of Table 1 were developed assuming a 15–20 percent leaching fraction range which results in an average soil-water salinity (ECsw) approximately 3 times that of the applied water. The soil-water salinity (ECsw) is the average root zone salinity to which the plant is exposed. It is difficult to measure. Salinity measurement is normally done on a saturation extract of the soil and referred to as the soil salinity (ECe). This soil salinity, (ECe), is approximately equal to one-half of the soil-water salinity (ECsw). As a general rule of thumb, at a 15–20 percent leaching fraction, salinity of the applied water (ECw) can be used to predict or estimate soil-water salinity (ECsw) or soil salinity (ECe) using the following equations:

$$EC_{sw} = 3\ EC_w \quad (4)$$

$$EC_e = 1.5\ EC_w \quad (5)$$

$$EC_{sw} = 2\ EC_e \quad (6)$$

If irrigation practices result in greater or less leaching than the 15–20 percent LF assumed in the guidelines of Table 1, a more correct concentration factor can be calculated using a new estimated average leaching fraction and the procedure illustrated in Example 2. Table 3 lists concentration factors for a wide range of leaching fractions (LF = 0.05 to 0.80). The predicted average soil salinity (ECe) is estimated by multiplying the irrigation water salinity (ECw) by the appropriate concentration factor for the estimated leaching fraction (see equation (8) in Table 3). These predicted average soil salinities reflect changes due to long-term water use and not shortterm changes that may occur within a season or between irrigations. Figure 2 illustrates typical soil salinity profiles that can be identified and are typical of salinity distribution in the crop root zone after several years of irrigation with one water source and closely similar leaching fractions.

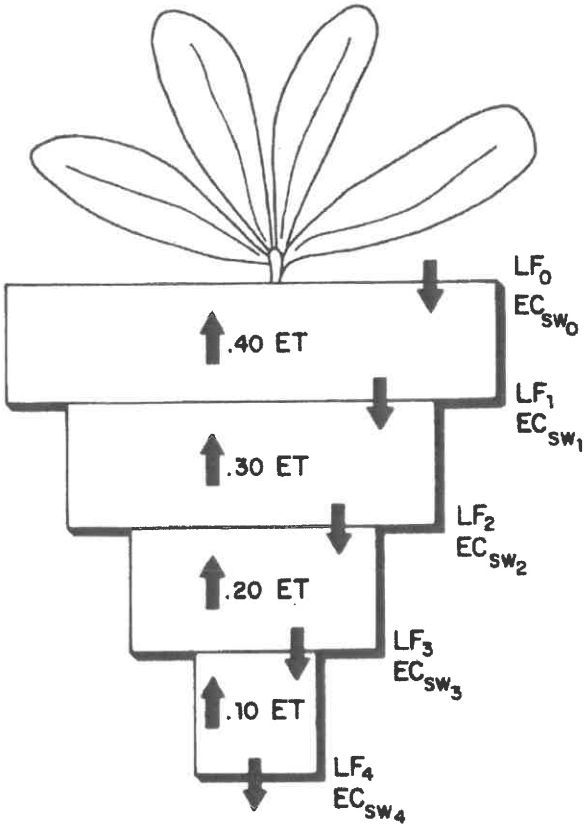
2.3 SALINITY EFFECTS ON CROPS

The primary objective of irrigation is to provide a crop with adequate and timely amounts of water, thus avoiding yield loss caused by extended periods of water stress during stages of crop growth that are sensitive to water shortages. However, during repeated irrigations, the salts in the irrigation water can accumulate in the soil, reducing water available to the crop and hastening the onset of a water shortage. Understanding how this occurs will help suggest ways to counter the effect and reduce the probability of a loss in yield.

The plant extracts water from the soil by exerting an absorptive force greater than that which holds the water to the soil. If the plant cannot make sufficient internal adjustment and exert enough force, it is not able to extract sufficient water and will suffer water stress. This happens when the soil becomes too dry. Salt in the soil-water increases the force the plant must exert to extract water and this additional force is referred to as the osmotic effect or osmotic potential. For example, if two otherwise identical soils are at the same water content but one is salt-free and the other is salty, the plant can extract and use more water from the salt-free soil than from the salty soil. The reasons are not easily explained. Salts have an affinity for water. If the water contains salt, more energy per unit of water must be expended by the plant to absorb relatively salt-free water from a relatively salty soil-water solution.

EXAMPLE 2 - DETERMINATION OF AVERAGE ROOT ZONE SALINITY

The average root zone salinity can be calculated using the average of five points in the rooting depth. The following procedure can be used to estimate the average root zone salinity to which the crop responds.



ASSUMPTIONS

1. Applied water salinity (EC_w) = 1 dS/m.
2. Crop water demand (ET) = 1000 mm/season.
3. The crop water use pattern is 40-30-20-10. This means the crop will get 40 percent of its ET demand from the upper quarter of the root zone, 30 percent from the next quarter, 20 percent from the next, and 10 percent from the lowest quarter. Crop water use will increase the concentration of the soil-water which drains into the next quarter (EC_{sw}) of the root zone.
4. Desired leaching fraction (LF) = 0.15. The leaching fraction of 0.15 means that 15 percent of the applied irrigation water entering the surface percolates below the root zone and 85 percent replaces water used by the crop to meet its ET demand and water lost by surface evaporation.

EXPLANATION

1. Five points in the root zone are used to determine the average root zone salinity. These five points are soil-water salinity at (1) the soil surface, (ECsw0); (2) bottom of the upper quarter of the root zone, (ECswl); (3) bottom of the second quarter depth, (ECsw2); (4) bottom of the third quarter, (ECsw3) and (5) bottom of the fourth quarter or the soil-water draining from the root zone (ECsw4) which is equivalent to the salinity of the drainage water (ECdw).
2. With a LF of 0.15, the applied water (AW) needed to meet both the crop ET and the LF is determined from the following equation:

$$AW = \frac{ET}{1 - LF} = 1176 \text{ mm of water} \quad (7)$$

3. Since essentially all the applied water enters and leaches through the soil surface, effectively removing any accumulated salts, the salinity of the soil water at the surface (ECsw0) must be very close to the salinity of the applied water as shown using equation (3) and assuming LF0 = 1.0.

$$EC_{dw_0} = EC_{sw_0} = \frac{EC_w}{LF_0} = \frac{1}{1} = 1 \text{ dS/m} \quad (3)$$

4. The salinity of the soil-water draining from the bottom of each root zone quarter is found by determining the leaching fraction for that quarter using equation (2) and then determining the soil-water salinity using equation (3).

$$LF = \frac{\text{Water leached}}{\text{Water applied}} \qquad EC_{sw} = \frac{EC_w}{LF}$$

For the bottom of the first quarter:

$$LF_1 = \frac{1176-.40(1000)}{1176} = 0.66 \qquad EC_{sw_1} = \frac{EC_w}{LF_1} = 1.5 \text{ dS/m}$$

--- at the bottom of the second quarter:

$$LF_2 = \frac{1176-.40(1000)-.30(1000)}{1176} = 0.40 \qquad EC_{sw_2} = \frac{EC_w}{LF_2} = 2.5 \text{ dS/m}$$

--- at the bottom of the third quarter:

$$LF_3 = \frac{1176-.40(1000)-.30(1000)-.20(1000)}{1176} = 0.23 \qquad EC_{sw_3} = \frac{EC_w}{LF_3} = 4.3 \text{ dS/m}$$

--- at the bottom of the root zone (fourth quarter):

$$LF_4 = \frac{1176-.40(1000)-.30(1000)-.20(1000)-.10(1000)}{1176} = 0.15 \qquad EC_{sw_4} = \frac{EC_w}{LF_4} = 6.7 \text{ dS/m}$$

5. The average soil-water salinity of the root zone is found by taking the average of the five root zone salinities found above:

$$EC_{sw} = \frac{EC_{sw_0} + EC_{sw_1} + EC_{sw_2} + EC_{sw_3} + EC_{sw_4}}{5}$$

$$EC_{sw} = \frac{1.0 + 1.5 + 2.5 + 4.3 + 6.7}{5} = 3.2 \text{ dS/m}$$

6. This calculation shows that the average soil-water salinity of the root zone will be 3.2 times as concentrated as the applied water.

Table 3 CONCENTRATION FACTORS (X) FOR PREDICTING SOIL SALINITY (ECe) [1] FROM IRRIGATION WATER SALINITY (ECw) AND THE LEACHING FRACTION (LF)

Leaching Fraction (LF)	Applied Water Needed (Percent of ET)	Concentration Factor [2] (X)
0.05	105.3	3.2
0.10	111.1	2.1
0.15	117.6	1.6
0.20	125.0	1.3
0.25	133.3	1.2
0.30	142.9	1.0
0.40	166.7	0.9
0.50	200.0	0.8
0.60	250.0	0.7
0.70	333.3	0.6
0.80	500.0	0.6

[1] The equation for predicting the soil salinity expected after several years of irrigation with water of salinity ECw is:

$$EC_e \text{ (dS/m)} = EC_w \text{ (dS/m)}.X \quad (8)$$

[2] The concentration factor is found by using a crop water use pattern of 40-30-20-10. The procedure is shown in example 2.

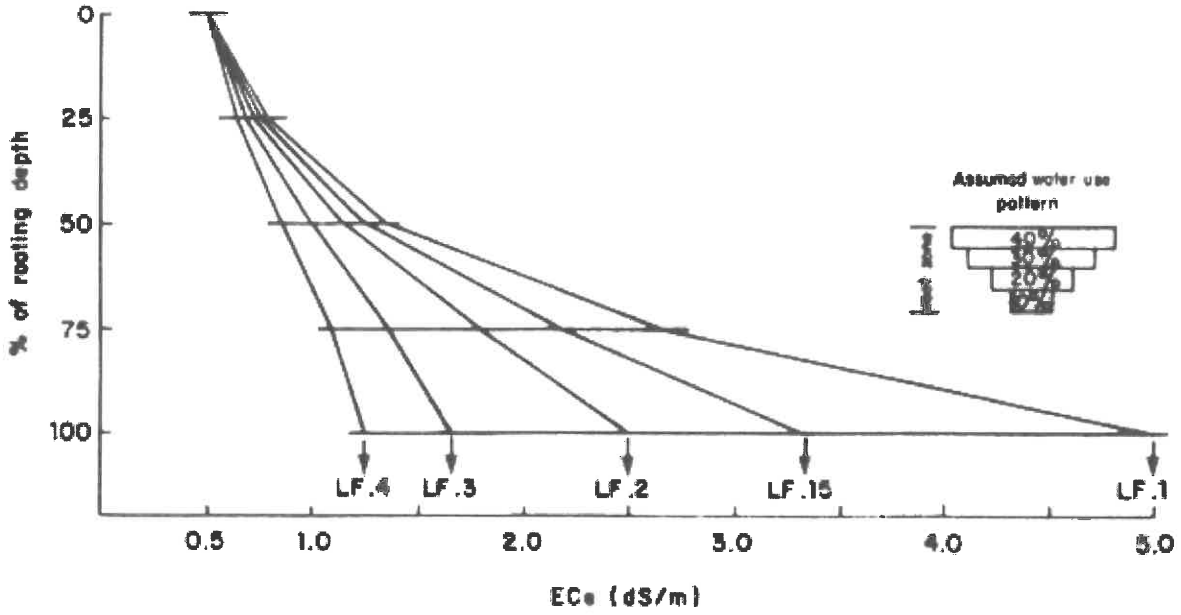


Fig. 2 Salinity profile expected to develop after long-term use of water of EC_w = 1.0 dS/m at various leaching fractions (LF)

For all practical purposes, the added energy required to absorb water from the salty soil (osmotic potential) is additive to the energy required to absorb water from a salt-free soil (soil-water potential). The cumulative effect is illustrated in Figure 3 and results in an important reduction in water available to the crop as salinity increases. Salinity effects are closely analogous to those of drought as both result in water stress and reduced growth. Stunting, leaf damage and necrosis or obvious injury to the plant are only noticeable after prolonged exposure to relatively high salinity.

The previous discussion showed how the concentration of salts in the soil varied with leaching fraction and depth in the root zone and resulted in an increase in concentration as the leaching fraction decreases or with increasing depth in the root zone. As the soil dries, the plant is also exposed to a continually changing water availability in each portion of the rooting depth since the soil-water content (soil-water potential) and soil-water salinity (osmotic potential) are both changing as the plant uses water between irrigations. The plant absorbs water but most of the salt is excluded and left behind in the root zone in a shrinking volume of soil-water. Figure 4 shows that following an irrigation, the soil salinity is not constant with depth. Following each irrigation, the soil-water content at each depth in the root zone is near the maximum, and the concentration of dissolved salts is near the minimum. Each changes, however, as water is used by the crop between irrigations.

The plant exerts its absorptive force throughout the rooting depth and takes water from wherever most readily available (the least resistance to absorption). Usually this is the upper root zone, the area most frequently replenished by irrigation and rainfall. Since more water passes through this upper root zone, it is more thoroughly leached and the osmotic or salinity effects are much less than at greater depths. Between irrigations, the upper root zone dries more rapidly than the lower because of the proliferation of roots in this zone which extract the readily available soil moisture. The plant must then meet more of its water demand from increasingly greater depths as the upper soil-water is depleted. Both the soil moisture at depth and the soil moisture remaining in the upper portions have a higher soilwater salinity and thus a greater osmotic potential. As the plant depletes the soil-water, a water extraction pattern develops. The extraction pattern of 40, 30, 20 and 10 percent for the upper to lower quarters of

the root zone is assumed in the guidelines in Table 1. This closely fits water extraction patterns under normal irrigation practices and is assumed throughout this paper.

The pattern for water uptake is closely related to the frequency of irrigation. With infrequent irrigations, as assumed for the guidelines in Table 1, the typical extraction pattern is 40-30-20-10, but for more frequent irrigations the water uptake pattern is skewed towards greater uptake from the upper root zone and less from the lower and the crop rooting depth tends to be at shallower depths. A typical extraction pattern might be 60-30-7-3. Whatever the frequency, irrigations must be timed to supply adequate water and prevent crop moisture stress between irrigations, especially if soil salinity is also affecting water availability.

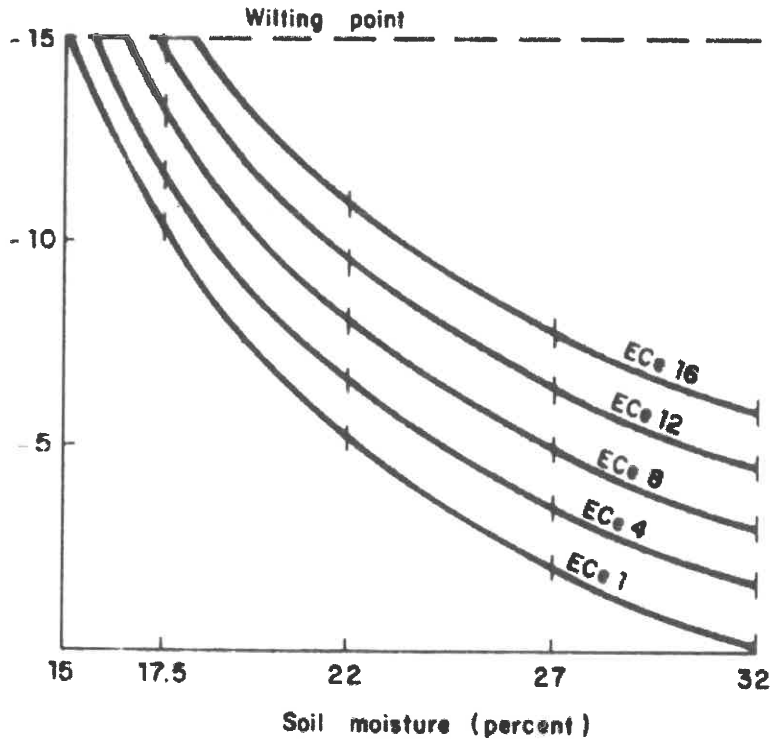
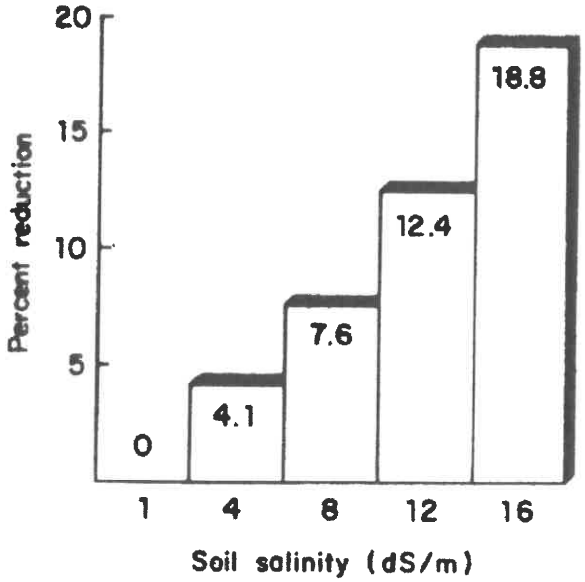


Fig 3 Soil moisture retention curves for a clay-loam Soil at varying degrees of soil salinity (EC_e)



Assumptions:

1. Salinity in irrigation water x 3 = salinity of soil-water.
2. No removals or additions of salts from the soil-water.
3. Soil-water depletion effects and salinity effects on water availability are additive (EC x .36 = osmotic pressure).
4. Available soil-water is difference between % soil-water at water holding capacity and at wilting point.
5. Evapotranspiration (ET) by the crop is removing water from the soil.

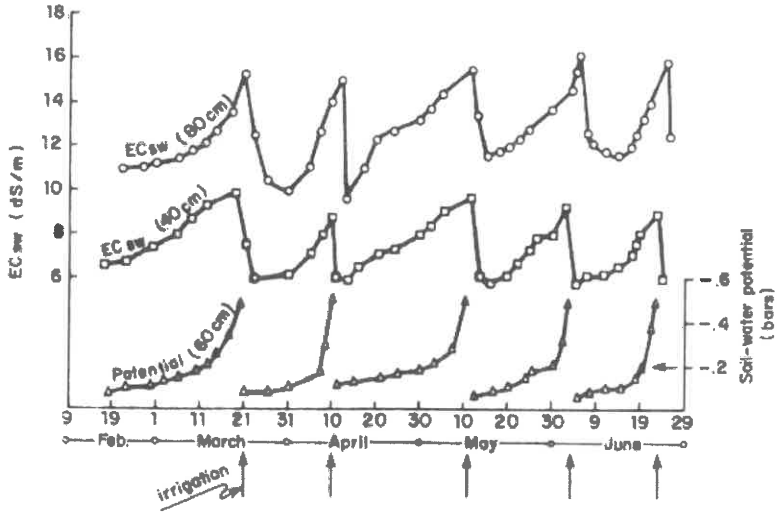


Fig.4 Change in salinity of soil-water (EC_{sw}) between irrigations of alfalfa due to ET use of stored water (Rhoades 1972)

When the upper rooting depth is well supplied with water, salinity in the lower root zone becomes less important. However, if periods between irrigations are extended and the crop must extract a significant portion of its water from the lower depths, the deeper root zone salinity becomes important particularly if, in the latter stages of a 'dry-down' (soil moisture depletion) period between irrigations, a high crop water demand should occur, such as on a hot, windy day. In this case, absorption and water movement toward the roots may not be fast enough to supply the crop and a severe water stress results. Reduced yields or crop damage can be expected for most crops when there is a shortage of water for a significant period of time.

The preceding discussion assumes that salinity reduces water availability in a similar manner for all types of plants, but not all crops are equally affected at the same soil salinity. Some are more able than others to extract or absorb water from a salty soil and are, therefore, more tolerant of salinity. The reasons for differences in tolerance are not well understood, but tolerance data show that there is an 8 to 10-fold range in salt tolerance of agricultural crops. In areas where irrigation management (leaching) cannot control salinity within the tolerance of a preferred crop, a yield loss will result unless an alternate crop more tolerant to the expected salinity is planted. A detailed discussion of crop tolerance to salinity is presented in Section 2.4.3.

3. INFILTRATION PROBLEMS

3.1 THE INFILTRATION PROBLEM

An infiltration problem occurs if the irrigation water does not enter the soil rapidly enough during a normal irrigation cycle to replenish the soil with water needed by the crop before the next irrigation. The reduced infiltration rate, if due to quality of applied water, is generally a problem within the upper few centimetres of soil but occasionally may occur at greater depths. The end result is a decrease in water supply to the crop, similar to the reduction due to salinity, but for a different reason. A water infiltration problem reduces the quantity of water put into the soil for later use by the crop while salinity reduces the availability of the water in storage.

Infiltration refers to the entry of water into the soil. The rate at which water enters is referred to as the rate of infiltration. Permeability, the term used in the previous edition of Irrigation and Drainage Paper 29 (1976), more correctly refers to the percolation of infiltrated water through the soil. Since the water quality problem is primarily one related to the ease with which water enters and moves through the upper few centimetres of soil, we have chosen the term 'infiltration problem' rather than the previously used term 'permeability problem'. An infiltration rate as low as 3 mm/hour is considered low while a rate above 12 mm/hour is relatively high. This can be affected, however, by many factors other than water quality, including physical characteristics of the soil, such as soil texture and type of clay minerals, and chemical characteristics including exchangeable cations. The guidelines of Table 1 refer to infiltration problems as they relate directly to the unfavourable changes in soil chemistry caused by the quality of irrigation water applied. These problems concern both salinity and relative sodium content in the applied water. Figure 21 shows in graphic form that both salinity (ECw) and the sodium adsorption ratio (SAR) of the applied water affect the rate of infiltration of water into surface soil. Figure 21 can be used in place of the numerical evaluations in Table 1 given for infiltration problems.

The infiltration rate generally increases with increasing salinity and decreases with either decreasing salinity or increasing sodium content relative to calcium and magnesium - the sodium adsorption ratio. Therefore, the two factors, salinity and SAR, must be considered together for a proper evaluation of the ultimate effect on water infiltration rate.

3.1.1 Infiltration Problem Evaluation

Low salinity water (less than 0.5 dS/m and especially below 0.2 dS/m) is corrosive and tends to leach surface soils free of soluble minerals and salts, especially calcium, reducing their strong stabilizing influence on soil aggregates and soil structure. Without salts and without calcium, the soil disperses and the dispersed finer soil particles fill many of the smaller pore spaces, sealing the surface and greatly reducing the rate at which water infiltrates the soil surface. Soil crusting and crop emergence problems often result, in addition to a reduction in the amount of water that will enter the soil in a given amount of time and which may ultimately cause water stress between irrigations.

Very low salinity water (less than ECw = 0.2 ds/m) almost invariably results in water infiltration problems, regardless of the relative sodium ratio (or SAR). Rainfall is a very low salinity water and irrigated areas frequently experience exceptionally low rates of infiltration of rainfall resulting in excessive runoff.

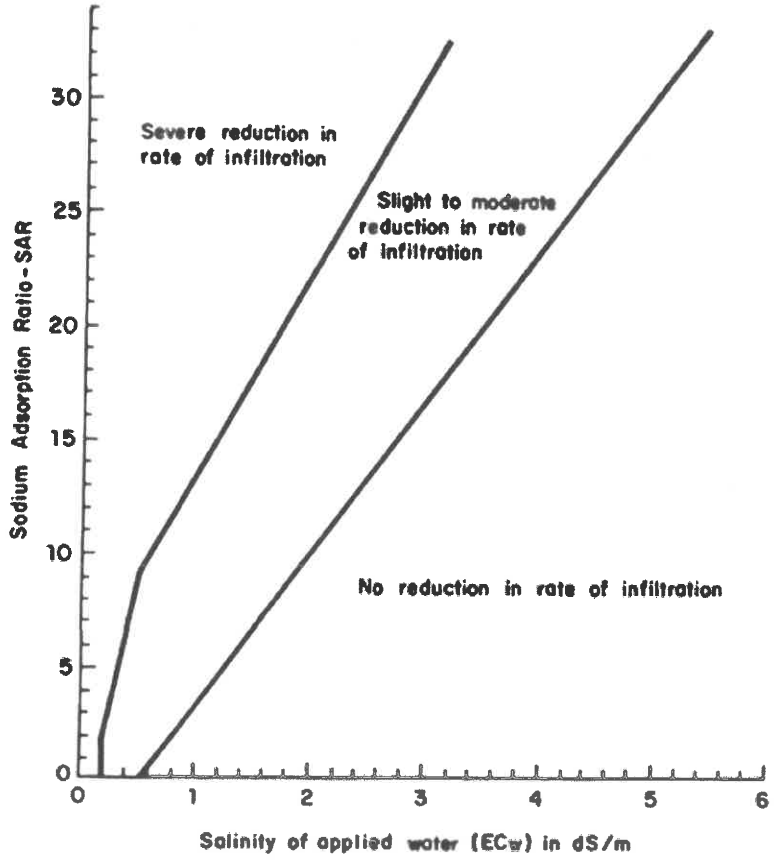


Fig. 21 Relative rate of water infiltration as affected by salinity and sodium adsorption ratio (Adapted from Rhoades 1977; and Oster and Schroer 1979)

Excessive sodium in irrigation water also promotes soil dispersion and structural breakdown but only if sodium exceeds calcium by more than a ratio of about 3:1. Such a relatively high sodium content (>3:1) often results in a severe water infiltration problem due to soil dispersion and plugging and sealing of the surface pores, in much the same way as does the very low salinity water. This is due to lack of sufficient calcium to counter the dispersing effects of the sodium. Excessive sodium may also make it extremely difficult to supply enough water to meet the crop water demand. Other related problems such as soil crusting, poor seedling emergence, lack of aeration, plant and root diseases, weed and mosquito control problems caused by the low rate of infiltration may further complicate crop management.

In the past, several procedures have been used to predict a potential infiltration problem. The Residual Sodium Carbonate (RSC) method (Eaton 1950; Richards 1954) was widely used at one time. The most commonly used recent method to evaluate the infiltration problem potential has been and probably still is the Sodium Adsorption Ratio (SAR) (Richards 1954). The SAR equation (1) as given in Figure 1 is:

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}} \qquad (1)$$

where: Na = sodium in me/l
Ca = calcium in me/l
Mg = magnesium in me/l

In recent reports and journal articles, SAR is more and more frequently being reported as RNa and not SAR. The terms are synonymous. The SAR procedure encompasses the infiltration problems due to an excess of sodium in relation to calcium and magnesium. It does not take into account changes in calcium in the soil water that take place because of changes in solubility of calcium resulting from precipitation or dissolution during or following an irrigation. Sodium, an important part of salinity, remains soluble and in equilibrium with exchangeable soil sodium at all times. Whether concentrated from with-drawal of water by the crop between long irrigation intervals, diluted with applied water, or leached away in drainage, outside influences have little effect on sodium solubility or precipitation. Calcium, however, does not remain completely soluble or in constant supply but is constantly changing until an equilibrium is established. Calcium changes occur due to dissolution of soil minerals into the soil-water thus raising its calcium content, or to precipitation from soil-water, usually as calcium carbonate, thus reducing the calcium. Dissolution is encouraged by dilution and by carbon dioxide dissolved in the soil-water; precipitation may take place because of the presence of sufficient calcium along with enough carbonate, bicarbonate or sulphates to exceed the solubility of calcium carbonate (limestone) or calcium sulphate (gypsum). Soon after an irrigation, dissolution or precipitation may occur, changing the supply of calcium and establishing an equilibrium at a new calcium concentration, different to that in the applied water. The SAR equation, since it does not account for these changes, is therefore somewhat in error. However, the SAR equation and procedure is still considered an acceptable evaluation procedure for most of the irrigation water encountered in irrigated agriculture.

NOTE

The adjusted SAR procedure presented in the previous edition of this paper (Ayers and Westcot 1976) is no longer recommended. Oster and Rhoades (1977), Oster and Schroer (1979) and Suarez (1981) carefully evaluated that procedure and concluded that it overpredicts the sodium hazard. They suggest that, if used, the value obtained by that method should be further adjusted by an 0.5 factor to evaluate more correctly the effects of HCO_3 on calcium precipitation (adj SAR × 0.5).

In this present edition the newer adj RNa procedure of Suarez (1981) is recommended but both the older SAR procedure and the new adj RNa are acceptable, with a preference expressed towards the adj RNa because it and the Cax of Table II offer a better insight into the change in calcium in the soil-water due to addition by dissolution of calcium from soil carbonates and silicates, or loss of calcium from soil-water by precipitation as carbonates.

Table 11 CALCIUM CONCENTRATION (Ca_x) EXPECTED TO REMAIN IN NEAR-SURFACE SOIL-WATER FOLLOWING IRRIGATION WITH WATER OF GIVEN HCO_3/Ca RATIO AND EC_w [1,2,3]

		Salinity of applied water (EC_w) (dS/m)											
		0.1	0.2	0.3	0.5	0.7	1.0	1.5	2.0	3.0	4.0	6.0	8.0
Ratio of HCO_3/Ca	.05	13.20	13.61	13.92	14.40	14.79	15.26	15.91	16.43	17.28	17.97	19.07	19.94
	.10	8.31	8.57	8.77	9.07	9.31	9.62	10.02	10.35	10.89	11.32	12.01	12.56
	.15	6.34	6.54	6.69	6.92	7.11	7.34	7.65	7.90	8.31	8.64	9.17	9.58
	.20	5.24	5.40	5.52	5.71	5.87	6.06	6.31	6.52	6.86	7.13	7.57	7.91
	.25	4.51	4.65	4.76	4.92	5.06	5.22	5.44	5.62	5.91	6.15	6.52	6.82
	.30	4.00	4.12	4.21	4.36	4.48	4.62	4.82	4.98	5.24	5.44	5.77	6.04
	.35	3.61	3.72	3.80	3.94	4.04	4.17	4.35	4.49	4.72	4.91	5.21	5.45
	.40	3.30	3.40	3.48	3.60	3.70	3.82	3.98	4.11	4.32	4.49	4.77	4.98
	.45	3.05	3.14	3.22	3.33	3.42	3.53	3.68	3.80	4.00	4.15	4.41	4.61

.50	2.84	2.93	3.00	3.10	3.19	3.29	3.43	3.54	3.72	3.87	4.11	4.30
.75	2.17	2.24	2.29	2.37	2.43	2.51	2.62	2.70	2.84	2.95	3.14	3.28
1.00	1.79	1.85	1.89	1.96	2.01	2.09	2.16	2.23	2.35	2.44	2.59	2.71
1.25	1.54	1.59	1.63	1.68	1.73	1.78	1.86	1.92	2.02	2.10	2.23	2.33
1.50	1.37	1.41	1.44	1.49	1.53	1.58	1.65	1.70	1.79	1.86	1.97	2.07
1.75	1.23	1.27	1.30	1.35	1.38	1.43	1.49	1.54	1.62	1.68	1.78	1.86
2.00	1.13	1.16	1.19	1.23	1.26	1.31	1.36	1.40	1.48	1.54	1.63	1.70
2.25	1.04	1.08	1.10	1.14	1.17	1.21	1.26	1.30	1.37	1.42	1.51	1.58
2.50	0.97	1.00	1.02	1.06	1.09	1.12	1.17	1.21	1.27	1.32	1.40	1.47
3.00	0.85	0.89	0.91	0.94	0.96	1.00	1.04	1.07	1.13	1.17	1.24	1.30
3.50	0.78	0.80	0.82	0.85	0.87	0.90	0.94	0.97	1.02	1.06	1.12	1.17
4.00	0.71	0.73	0.75	0.78	0.80	0.82	0.86	0.88	0.93	0.97	1.03	1.07
4.50	0.66	0.68	0.69	0.72	0.74	0.76	0.79	0.82	0.86	0.90	0.95	0.99
5.00	0.61	0.63	0.65	0.67	0.69	0.71	0.74	0.76	0.80	0.83	0.88	0.93
7.00	0.49	0.50	0.52	0.53	0.55	0.57	0.59	0.61	0.64	0.67	0.71	0.74
10.00	0.39	0.40	0.41	0.42	0.43	0.45	0.47	0.48	0.51	0.53	0.56	0.58
20.00	0.24	0.25	0.26	0.26	0.27	0.28	0.29	0.30	0.32	0.33	0.35	0.37
30.00	0.18	0.19	0.20	0.20	0.21	0.21	0.22	0.23	0.24	0.25	0.27	0.28

[1] Adapted from Suarez (1981).

[2] Assumes a soil source of calcium from lime ($CaCO_3$) or silicates; no precipitation of magnesium, and partial pressure of CO_2 near the soil surface (P_{CO_2}) is .0007 atmospheres.

[3] Ca_x, HCO_3, Ca are reported in me/l; EC_w is in dS/m.

An alternative procedure, discussed in the following paragraphs, takes a new look at the older SAR equation and adjusts the calcium concentration of the irrigation water to the expected equilibrium value following an irrigation, and includes the effects of carbon dioxide (CO_2), of bicarbonate (HCO_3) and of salinity (ECw) upon the calcium originally present in the applied water but now a part of the soil-water. The procedure assumes a soil source of calcium - from soil lime ($CaCO_3$) or other soil minerals such as silicates - and no precipitation of magnesium.

The new term for this is adj RNa (adjusted Sodium Adsorption Ratio) and the calculation procedure is presented in the following example as an improvement on the older Sodium Adsorption Ratio (SAR). It can be used to predict more correctly potential infiltration problems due to relatively high sodium (or low calcium) in irrigation water supplies (Suarez 1981; Rhoades 1982) and can be substituted for SAR in Table 1. The equation for calculation of adj RNa of the surface soil is very similar to the older SAR equation and is:

$$\text{adj } R_{Na} = \frac{Na}{\sqrt{\frac{Ca_x + Mg}{2}}} \qquad (14)$$

where: Na = sodium in the irrigation water reported in me/l

Ca_x = a modified calcium value taken from Table 11, reported in me/l. Cax represents Ca in the applied irrigation water but modified due to salinity of the applied water (ECw), its HCO_3/Ca ratio (HCO_3 and Ca in me/l) and the estimated partial pressure of CO_2 in the surface few millimetres of soil (P_{CO2} = 0.0007 atmospheres)

Mg = magnesium in the irrigation water reported in me/l

To use the Cax table (Table 11), first determine the HCO_3 to Ca ration (HCO_3/Ca) and ECw from the water analysis, using HCO_3 and Ca in me/l and the water salinity (ECw) in deciSiemens per metre. An appropriate range of calculated HCO_3/Ca ratios appears on the left side of the table and the range of ECw across the top. Find the HCO_3/Ca ratio that falls nearest to the calculated HCO_3/Ca value for the subject water and read across to the ECw column that most closely approximates the ECw for the water being evaluated. The Cax value shown represents the me/l of Ca that is expected to remain in solution in the soil water at equilibrium and is to be used in equation (14). In Example 6, the three calculation procedures are compared 1) SAR, 2) adj SAR from FAO-29 1976, and 3) adj RNa.

The adj RNa obtained is used in place of the SAR in Table I to evaluate better the potential of the water to cause an infiltration problem if used for irrigation. Comparison of SAR and adj RNa for various types of water from around the world are presented in Annex I. The data in Annex I show that for most water, the SAR calculation is within ±10 percent of the value obtained after adjustment of the calcium concentration using equation (14) and Table 11.

If computer facilities are available, a simulation model can be relied upon to give valid evaluations of these adjusted sodium adsorption ratios (adj RNa). The adj RNa outlined in the foregoing is adapted from the procedure of Suarez (1981). A computer simulation model is also available (Rhoades 1982). Both give closely comparable results.

EXAMPLE 6 - COMPARISON OF METHODS TO CALCULATE THE SODIUM HAZARD OF A WATER

Given: The water analysis is:

Ca	=	2.32 me/l
Mg	=	1.44 me/l
Na	=	7.73 me/l
Sum	=	11.49 me/l
CO_3	=	0.42 me/l
HCO_3	=	3.66 me/l
Sum	=	4.08 me/l
EC_w	=	1.15 dS/m

Explanation: 1. The Sodium Adsorption Ratio (SAR) can be calculated from equation (1):

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}} \qquad (1)$$

$$SAR = \frac{7.73}{\sqrt{\frac{2.32 + 1.44}{2}}} = 5.64$$

2. The adjusted Sodium Adsorption Ratio (adj SAR) can be calculated from the procedure given in Ayers and Westcot (1976): adj SAR = SAR [1 + (8.4 - pHc)] (15)

where $pHc = (pk_2 - pk_c) + p(Ca + Mg) + p(Alk)$

$(pk_2 - pk_c) = 2.3$

p (Ca + Mg) = 2.3
p (Alk) = 2.4
pHc = 7.4

adj SAR = 5.64 [1 + (8.4 - 7.40] = 11.3

3. The adjusted Sodium Adsorption Ratio (adj RNa) can be calculated from equation (14) and Table 11):

$$\text{adj } R_{Na} = \frac{Na}{\sqrt{\frac{Ca_x + Mg}{2}}} \qquad (14)$$

EC_w = 1.15 dS/m
HCO_3/Ca = 1.76

From Table 11, Ca_x = 1.43 me/l

$$\text{adj } R_{Na} = \frac{7.73}{\sqrt{\frac{1.43 + 1.44}{2}}} = 6.45$$

3.2 MANAGEMENT OF INFILTRATION PROBLEMS

Irrigating to fill the soil-water reservoir for later withdrawal by the crop is difficult when infiltration rates are low, but there is little need to take action to increase infiltration unless the crop water demand or the leaching requirement cannot be met. Water ponding for too long a time frequently gives rise to secondary problems which are as important in causing yield loss as is an actual water shortage and often determine remedial measures to correct the infiltration problem. Some of the more troublesome secondary problems are crusting of seed beds, excessive weed growth and surface saturation which can cause root rot, diseases, nutritional disorders, poor aeration and poor germination. In some cases, water ponding for an excessive period of time has caused mosquito problems.

The management steps available to help maintain yields can be either chemical or physical. Chemical practices involve changing the soil or water chemistry that influences soil infiltration rates. This is normally accomplished by adding a chemical amendment, such as gypsum, to either the soil or the water or, in a few cases, by blending two or more sources of water to reduce the potential hazard. Physical methods include cultural practices that can be expected to improve or maintain infiltration rates during periods of irrigation or rainfall. Whether the physical or chemical approach is used, local conditions play an important role. A reduced infiltration caused by water quality is a different problem to a low infiltration rate caused by a clayey or compacted surface soil. Infiltration problems due to water quality are related to the impurities (Ca, Mg, Na, HCO_3 and ECw) present in the water supply. Several possible options to solve a water quality-related infiltration problem are discussed in the following paragraphs. Each must be adapted to the local conditions and thoroughly field tested before any large-scale implementation.

The following management steps are directed at evaluating and overcoming infiltration problems caused by the chemical quality of the irrigation supply. Of equal importance, and also a water quality problem, is the reduction in infiltration that can take place due to a high sediment content

in the supply water. It is beyond the scope of this publication to include this factor but it should be considered. See Section 8.17 for an example of the impacts from sediment.

3.2.1. Soil and Water Amendments

Certain chemical amendments added to soil or water should improve a low infiltration rate caused by low salinity or by excessive sodium (high SAR) in the irrigation water. Improvement can be expected if the amendment increases the soluble calcium content or causes a significant increase in the salinity (ECw) of the applied water. Amendments are used to help increase the infiltration or counter the effects of sodium, since, at present, there is no economical process available for removing salts or sodium from irrigation water which is low enough in cost for general agricultural use. An amendment, such as gypsum, when added to soil or water will increase the calcium concentration in the water, thus reducing the sodium to calcium ratio and the SAR. Adding gypsum is also beneficial because it increases the salinity of low salt waters, thus improving infiltration (Figure 21). Gypsum of other similar additives will not cause any important improvement if poor infiltration is due to adverse soil texture, soil compaction, restrictive claypan or hardpan layers, or a high water table.

Most soil and water amendments in common use supply calcium directly (gypsum) or indirectly through an acid or acid-forming substance (sulphuric acid or sulphur) which reacts with soil lime ($CaCO_3$) to release calcium to the soil solution. Acid or acid-forming amendments are not effective if lime is absent from the soil. Chemical amendments are expensive and add to the cost of crop production. They are justified only if their use results in a substantial improvement that can be evaluated in relation to cost. Field trials should be conducted to determine whether water or soil amendments improve water penetration or yield to an extent that justifies the cost. A crop receiving adequate water and producing near maximum yield would not be expected to show a further yield increase from the use of amendments, but, in some instances, such amendments may make irrigation management easier, though at an increased cost for the amendments, their handling and application.

Water amendments are most effective if the water infiltration problem is caused by a low salinity water (ECw < 0.2 dS/m) or by high SAR in a water of low to moderate salinity (ECw < 1.0 dS/m). If water salinity is moderate to high (ECw > 1.0 dS/m) in addition to a high SAR, soil applied amendments such as low-grade gypsum or sulphur may be preferred and often are more effective.

i. Gypsum

Gypsum can be either a soil or water amendment and is the most commonly used and widely available amendment for both. For reclamation of sodic soils, gypsum, in granular form, is applied broadcast at rates ranging from 5 to 40 t/ha and is worked into the soil. The 40 t/ha rate is used as a one-time application for extremely sodic soils and if rapid reclamation is needed. Annual rates of application in excess of 10 t/ha are usually uneconomical. High rates over 10 t/ha have normally been for immediate soil reclamation to allow roots to establish a proper rooting depth.

A water infiltration problem caused by low ECw or high SAR occurs primarily in the upper few centimetres of soil; therefore, the low application rates of gypsum to correct the surface problem are more effective if left on the soil surface or mixed with soil to a shallow depth rather than incorporated deeper into the soil as for reclamation. However, surface applied gypsum may be rapidly leached and the soil will again show the infiltration problem even though the gypsum may still be present a few centimetres below the soil surface. Small but repeated soil applications may be more effective for water-related surface infiltration problems, whereas single, large applications are more effective for sodic soil reclamation.

The application of gypsum to irrigation water to solve a water-related infiltration problem usually requires less gypsum per hectare than does a soil application. Gypsum is particularly effective when added to water if the water salinity is low (EC less than 0.5 dS/m). It is much less effective for higher salinity water because of the difficulty in applying and getting sufficient calcium into solution to counter the sodium present effectively. In practice it is unusual to get more than 1 to 4 me/l dissolved Ca in the usual fast-moving irrigation stream. These relatively small amounts of calcium in a low salinity water may increase infiltration by as much as 100-300 percent - a significant increase. However, if water salinity is relatively high, these small amounts of calcium are much less effective and change the infiltration rate to a much lesser degree.

The rate at which gypsum goes into solution will depend to a great extent upon the surface area or fineness of the grind. Finely-ground gypsum (less than 0.25 mm in diameter) dissolves much more rapidly. Therefore, the finely-ground, usually purer grades of gypsum are generally more satisfactory for water applications; the biggest drawback is the higher cost which often prevents small farmers from maintaining a continuous supply. The coarse grinds and lower grades are more satisfactory for soil application, but with care and ingenuity farmers have successfully used low grades for water amendments. Even though the finely-ground gypsum is much more costly per unit than is the coarse and lower grade, for water application the ease of handling and speed of dissolution often make it worth the added cost. Example 7 illustrates how gypsum can be used as a water amendment to improve infiltration.

EXAMPLE 7 - USE OF GYPSUM AS AN AMENDMENT

A low salinity water (ECw = 0.15 dS/m) is being used for irrigation of citrus. Infiltration problems have been experienced in the past causing oxygen stress in the citrus trees. The cause has been attributed to water ponding on the soil surface for extended periods of time. Since the critical time of fruit set is taking place, it was decided to add gypsum to the irrigation water to increase infiltration and reduce waterlogging and oxygen stress. A 5 hectare area needs an irrigation depth of 100 mm. The gypsum available is 70 percent pure and an increase of 2 me/l of calcium is desired in the water. How much gypsum should be used?

Given: ECw = 0.15 dS/m
Area = 5 ha
Gypsum = 70 percent pure

Total water requirement = 500 hectare mm = 5000 m^3
1 milliequivalent per litre of calcium = 86 kg of 100% gypsum per 1000 m^3 of water

Explanation: The amount of 100 percent gypsum needed to supply 2 me/l of Ca in 5000 m^3 of water can be found by:

1. 1 me/l (Ca) = 86 kg (100% gypsum)/1000 m^3
2. For 1 me/l (Ca) in 5000 m^3
   1 me/l (Ca) = 5 × 86 = 430 kg of 100% gypsum
3. For 2 me/l (Ca) in 5000 m^3
   2 me/l (Ca) = 430 kg × 2 = 860 kg of 100% gypsum
4. Since the gypsum is only 70% pure, the amount of gypsum needed is found by (860 × 100) ÷ 70 = 1230 kg of 70% pure gypsum
   A finely ground gypsum is best for water applications. Therefore the total quality of gyspum needed to supply 2 me/l of calcium in the 5000 m^3 of water is 1230 kg of 70% pure gypsum.

In a few instances, large pieces of rock gypsum have been placed in the irrigation ditch to supply calcium to the irrigation stream. The amount of calcium dissolving from the rock is low,

so effectiveness depends upon the stream velocity and volume. The amount being dissolved can be determined by comparing the calcium concentration of upstream water with the concentration downstream. Its probable effectiveness can then be estimated by the changes in ECw and SAR brought about by the additional calcium and the potential change in infiltration as predicted by the guidelines of Table 1. Rock gypsum placed in the irrigation channel may increase maintenance costs as weed control and watercourse maintenance become more difficult because the gypsum will have to be removed during mechanical cleaning or dredging.

The ultimate goal of either water or soil amendment with gypsum is an increase in yield or a substantial increase in ease of irrigation management. An effective treatment should improve the water infiltration rate but the improvement must be weighed against the costs to determine whether the treatment is worth-while.

Gypsum occurs naturally in many soils in arid climates and some soils will contain gypsum in sufficient quantity to affect interpretations of both soil salinity (ECe) and sodicity (exchangeable sodium), and require a correction both to the measured soil salinity (ECe) and to the reported SAR which is frequently used to estimate the soil exchangeable sodium percent (ESP) (see Figure 1). The ECe procedure involves a saturated soil paste and, if gypsum is present, the ECe will include salinity attributable to the dissolution of gypsum - about 2 dS/m. Since gypsum is generally beneficial to most soils and detrimental to very few crops (citrus), the additional soil salinity due to gypsum may be subtracted from the measured ECe to give a more correct assessment of the soil salinity hazard. For example, a gypsiferous soil has a measured ECe of 6 dS/m, a soil salinity which is expected to reduce yields of many salt sensitive crops. Since 2 dS/m of the reported ECe can be attributed to the gypsum, the ECe safely can be discounted by 2 dS/m and the corrected ECe now becomes ECe = 4 dS/m, an amount much less hazardous to sensitive crops.

Naturally occurring soil gypsum also has a bearing on interpretation of many laboratory analyses of soils. In soil analysis, the laboratory sometimes reports the SAR of the saturation extract (ESP), as shown in Figure 1. This is not a correct evaluation if gypsum is present because all the sodium salts are completely soluble whereas the gypsum is only slightly soluble and can contribute a maximum of about 20 to 30 me/l calcium to the saturation extract. As an example of the problem in interpretation, a strongly gypsiferous soil, but with high salinity, may have an ECe of 12 dS/m, of which 2 dS/m can be attributed to the gypsum. If all the other salts are sodium, there should be, in the saturation extract, Na = 100 me/l and Ca not more than 30 me/l, yielding a calculated SAR of 26. Such a soil, having ECe = 12 dS/m and SAR of the saturation extract equal to 26, is normally classified as a saline-alkali soil which requires extensive reclamation by a massive gypsum application plus extensive leaching before cropping. This is an incorrect interpretation. The soil is moderately saline (ECe = 12 dS/m) but it is not sodic because the gypsum provides a steady supply of calcium. Even without leaching, it should be capable of growing excellent barley (tolerance of barley = 10 dS/m at 90 percent yield potential) and with 50 percent reduction in salinity (to ECe = 7 dS/m including 2 dS/m per cm attributed to the naturally occuring gypsum in the soil), it could be planted to field crops such as barley, cotton, sugarbeets, grain sorghum, wheat and soybeans without a loss in yield caused by salinity. The soil is not sodic and does not require soil amendments, but it does need leaching to widen the range of crop adaptability. Such soils are sometimes called "self reclaiming", meaning that leaching alone will reclaim them and soil amendments are not needed.

A good rule of thumb to prevent such all-too-frequent interpretive errors has been adopted by the University of California Cooperative Extension Laboratories and is as follows: if the SAR of the saturation extract exceeds SAR = 10, confirmation of the indicated sodium problem is required by the laboratory. Confirmation is by the Schoonover Gypsum Requirement test given as method 22d in the USDA Handbook 60 (Richards 1954) or by the Exchangeable Cation Method given as methods 18 and 20a in the same handbook. These methods correct for the

soluble cations attributable to salinity and estimate SAR and ESP more correctly. Where appropriate, the Schoonover method is simple and reliable, but it is not appropriate if appreciable exchangeable potassium is present.

Gypsum is sometimes present in irrigation water. If the soluble salts in the irrigation water include appreciable calcium, many sodic soils can be reclaimed over a period of one to five or more years simply by planting tolerant crops and adopting cultural practices to promote deep percolation of applied irrigation water. To reclaim a severely sodic soil in one year may require up to 40 t/ha of gypsum and extensive leaching to remove sodium (salts) released during reclamation. To reclaim the same soil relying upon calcium present in the irrigation water (Ca = 2–3 me/l or more) plus cultural practices (disking, ploughing, deep cultivation) and planting sodium-tolerant crops (pasture grasses and forage or similar), may take several years. Success or failure will depend to a great extent upon an adequate rate of infiltration and the depth of water that enters the soil, the calcium content of the irrigation water and the severity of the sodic problem. Deep cultivation will greatly enhance infiltration and speed reclamation whether amendments are used or not.

ii. Acid-forming amendments

Acids or acid-forming amendments also supply calcium to soils, but lime ($CaCO_3$) must be present in the soil for them to be effective. Sulphur and sulphuric acid are both used extensively, but relatively few others have been used to any great extent. Table 12 gives comparative data for several common calcium supplying materials used for reclamation of sodic soil, but gypsum remains the most widely used because it is usually readily available and costs less for the me/l of calcium supplied. Several fertilizers are acid residual and contribute calcium through their acidic reaction.

Sulphur furnishes calcium if lime is present in the soil and is an excellent amendment for reclamation of sodic soils. It is not a satisfactory amendment for water application and is not very effective to improve a water infiltration problem. It is slow to react. The sulphur must first be acted upon by soil bacteria and be oxidized to form sulphurous and sulphuric acid which then reacts with lime to release calcium. The oxidation process is rather slow and requires a warm, well-aerated moist soil for about 30 days or longer. If sufficient time is available, it has proved to be a good amendment for reclamation of sodic-calcare-ous soils, but is not expected to provide a satisfactory solution for a water infiltration problem because the oxidation process is too slow and calcium released near the surface is soon leached during irrigations.

Sulphuric acid is a strong, corrosive acid, used for direct application to the soil surface at full strength or added to irrigation water where it reduces the water concentration of bicarbonate and contributes acidity to the soil surface to release calcium. It is very effective for reclaiming sodic soils and to improve water infiltration of limey soils because the sulphuric acid does not have to go through an oxidation process. It reacts rapidly with soil lime. Soil applications are made before cropping and are usually followed by extensive leaching to remove any excessive soluble salts present or formed because of the sulphuric acid reaction with lime and the soil. Applications in water must be carefully controlled and monitored to ensure that they are safe for the conditions of use - safe for pipelines, sprinklers, irrigation water distribution systems, and personnel. The ultimate effect on infiltration is about the same as that for a chemically equivalent amount of gypsum (Table 12). Sulphuric acid is highly corrosive and dangerous to handle. It may damage concrete pipelines, steel culverts, checkgates and aluminium pipes. It should only be applied by experienced operators.

Table 12 WATER AND SOIL AMENDMENTS AND THEIR RELATIVE EFFECTIVENESS IN SUPPLYING CALCIUM[1]

Amendment	Tons equivalent to 1 ton of 100 percent gypsum[2]

Gypsum ($CaSO_4 . 2H_2O$)*	1.00
Sulphur (S)**	0.19
Sulphuric acid (H_2SO_4)*	0.61
Ferric sulphate ($Fe_2(SO_4)_3 . 9H_2O$)**	1.09
Lime sulphur (9 percent Ca + 24 percent S)*	0.78
Calcium chloride ($CaCl_2 . 2H_2O$)*	0.86
Calcium nitrate ($Ca(NO_3)_2 . 2H_2O$)*	1.06
Calcium carbonate[3] ($CaCO_3$)**	0.58

* Suitable for use as a water or soil amendment

** Suitable only for soil application

[1] Adapted from Fireman and Branson (1965).

[2] The above are based on 100 percent pure materials. If not 100 percent,make the following calculation to find tons (X) that are equivalent to a100 percent material:

$$X = \frac{100 \cdot \text{tons}}{\text{percent purity}} \qquad (16)$$

Example: If gypsum is 50 percent pure, X = 2.00 tons. This says that2.00 tons of 50 percent pure gypsum is equivalent to 1 ton of 100 percent pure gypsum.

[3] For acid soils only.

Other amendments are sometimes used in local areas but their use depends greatly on the cost of supply and application. As shown in Table 13, several common fertilizers can also act as direct or indirect sources of calcium. Most acid fertilizers must go through an oxidation process similar to that for sulphur, and a source of calcium must be present in the soil ($CaCO_3$). Therefore, they are of limited value for a water infiltration problem, but may be useful to prevent or delay formation of a sodic soil that may gradually develop as a result of using a slightly marginal sodic water.

Table 13 AVERAGE COMPOSITION AND EQUIVALENT ACIDITY OR BASICITY OF FERTILIZER MATERIALS[1]

Fertilizer materials	Chemical Formula	Total Nitrogen (N)	Available Phosphoric Acid (P_2O_5)	Water Soluble Potash (K_2O)	Combined Calcium (Ca)	Combined Sulphur (S)	Equivalent[2] Acid or Base	
		Percent					in kg Acid	$Caco_3$ Base
Nitrogen materials								
Ammonium nitrate	NH_4NO_3	33.5–34					62	
Ammonium nitrate-sulphate	$NH_4NO_3.(NH_4)_2SO_4$	30					6.5	68
Monoammonium phosphate	$NH_4H_2PO_4$	11	48				58	
	$NH_4H_2PO_4.(NH_4)_2SO_4$	13	39			7	69	

Ammonium phosphate-sulphate								
Ammonium phosphate-sulphate	$NH_4H_2PO_4.(NH_4)_2SO_4$	16	20			15	88	
Ammonium phosphate-nitrate	$NH_4H_2PO_4.NH_4NO_3$	27	12			4.5	75	
Diammonium phosphate	$(NH_4)_2HPO_4$	16–18	46–48				70	
Ammonium sulphate	$(NH_4)_2SO_4$	21				24	110	
Anhydrous ammonia	NH_3	82					147	
Aqua ammonia	NH_4OH	20					36	
Calcium ammonium nitrate solution	$Ca(NO_3)_2.NH_4NO_3$	17			8.8		9	
Calcium nitrate	$Ca(NO_3)_2$	15.5			21			20
Calcium cyanamide	$CaCN_2$	20–22			37			63
Sodium nitrate	$NaNO_3$	16						29
Urea	$CO(NH_2)_2$	45–46					71	
Urea formaldehyde[3]		38					60	
Urea ammonium nitrate solution	$NH_4NO_3.CO(NH_2)_2$	32					57	
Phosphate materials								
Single superphosphate	$Ca(H_2PO_4)_2$		18–20		18–21	12		neutral
Triple superphosphate	$Ca(H_2PO_4)_2$		45–46		12–14	1		neutral
Phosphoric acid	H_3PO_4		52–54				110	
Superphosphoric acid[4]			76–83				160	
Potash materials								
Potassium chloride	KCl			60–62				neutral
Potassium nitrate	KNO_3	13		44			23	
Potassium sulphate	K_2SO_4			50–53		18		neutral
Sulphate of potashmagnesia	$K_2SO_4.2MgSO_4$			26	1	15		neutral

1 From Soil Improvement Committee (1975).

2 Equivalent per 100 kg of each material.

3 Also known as ureaform, reaction product of urea and formaldehyde.

4 H_3PO_4, $H_4P_2O_7$, $H_6P_4O_{13}$ and other higher forms.

3.2.2 Blending Water Supplies

As shown in Table 1, an SAR of 12 or greater may appreciably reduce the rate of infiltration of water with a salinity less than ECw of 2.9 dS/m, and an SAR as low as 6 may appreciably reduce the infiltration rate of water with a salinity less than ECw of 1.2 ds/m. The infiltration rate can be increased either by increasing the water salinity or reducing the SAR.

Dilution reduces the SAR. This is due to the nature of the SAR equation (1). The numerator (Na) is reduced in proportion to the dilution and at a greater rate than is the denominator (Ca + Mg) because the denominator is reduced by the square root of the dilution. Example 8 shows how the SAR of a blended water is reduced when a tubewell water in Pakistan is blended into the normal canal supplies. Without blending the tubewell water would have very limited use, but as a result of blending the total amount of usable water has increased by the amount supplied by the tubewell.

EXAMPLE 8 - BLENDING IRRIGATION WATER TO REDUCE THE SAR OF A POOR QUALITY SUPPLY

A canal water supply is available but will not meet the total crop water demand. The canal supply could be blended with a poorer quality well water to the extent of 75% canal water and 25% well water. What is the SAR of the blended water?

Given: The water analysis is:

	ECw (ds/m)	Ca (me/l)	Mg (me/l)	Na (me/l)	HCO_3 (me/l)	SAR
Canal water	0.23	1.41	0.54	0.48	1.8	0.5
Well water	3.60	2.52	4.00	32.0	4.5	18.0

Explanation: The resulting blend quality can be found by using equation (13):

(me/l of (a) x proportion of (a) used) +(me/l of (b) x proportion of (b) used) =resulting blend in me/l

Ca = (1.41×0.75) + (2.52×0.25) = 1.69 me/l (blend)

Mg = (0.54×0.75) + (4.00×0.25) = 1.41 me/l (blend)

Na = (0.48×0.75) + (32.0×0.25) = 8.36 me/l (blend)

HCO_3 = (1.8×0.75) + (4.5×0.25) = 2.48 me/l (blend)

EC = (0.23×0.75) + (3.6×0.25) = 1.07 dS/m (blend)

$$SAR = \frac{8.36}{\sqrt{\frac{1.69 + 1.41}{2}}} = 6.7$$

Many high SAR waters are usually abandoned if an alternate better quality source is made available. If the better supply is adequate for the area to be irrigated, there is nothing to be gained from blending the two supplies. However, if the better quality supply is not adequate for the land available for planting, blending a less desirable water with a better supply may allow more land to be planted, resulting in greater overall crop production and more income for the farmer.

Blending water supplies is not a common practice even when two supplies are available, one of which is much poorer in quality. Normally a better quality surface supply is used whenever available and the poorer quality groundwater is used whenever the surface supply is insufficient. Alternating supplies does not, however, offset an infiltration problem caused by the high SAR of

a poorer quality supply. In fact, the problem can be greatly aggravated if low salinity-low SAR supplies are used after a highly saline-high SAR water. The high SAR water causes a correspondingly high ESP in the surface soil and, if low salinity water is then used, it can soon cause an appreciably reduced infiltration rate. An even more severe problem occurs when rain falls after using a saline or high SAR irrigation water. A light application of surface applied gypsum (1 to 2 t/ha) prior to irrigation with the better quality supply or before the rainy season is sometimes used in an attempt to overcome this problem. Blending would also prevent many of the secondary problems caused by short-term usage of high SAR water, such as surface crusting and sealing. Wherever possible high SAR water should be diluted to reduce infiltration problems, but in those instances where its use is alternated, the use of supplemental amendments should be considered.

3.2.3 Cultivation and Deep Tillage

Soil and water amendments and blending change the chemical nature of the water while physical methods keep the soil open by mechanical means. The most common physical method is either cultivation or deep tillage. Both are effective but normally short-lived and are thus only temporary solutions to a water infiltration problem.

Cultivation is usually done for weed control or soil aeration rather than to improve water penetration. Where infiltration problems are severe, cultivation or tillage are helpful as they roughen the surface and slow the flow of water, increasing the time during which infiltration can take place. A rough, cloddy furrow or field improves infiltration during the first one or two irrigations, after which another cultivation may be needed. Cultivation equipment can often be modified to leave a rougher surface. Cultivation breaks up the crust in the upper few centimetres of soil to improve infiltration. A common practice in areas where a water infiltration problem has been caused by low salinity water is to cultivate before each irrigation or before every second irrigation. This roughens the soil and opens cracks and air spaces that greatly increase the surface area exposed for infiltration.

Deeper tillage (chiselling, subsoiling) can be expected to improve deep water penetration for only one or two irrigations since the soil surface soon reverts to its original condition but, although improvement is not permanent, this practice may temporarily allow sufficient water to enter to make an appreciable difference in stored water and in the crop yield. Deep tillage physically tears, shatters and rips the soil, and is done prior to planting or during periods of dormancy when root pruning or root disturbances of permanent crops are less disruptive. Deep tillage should only be performed when soils are dry enough to shatter and crack. If done wet, increased compaction, aeration and permeability problems can be expected.

3.2.4 Organic Residues

Crop residues or other organic matter left in the field will improve water penetration and is becoming a more widely accepted practice. It is one of the easiest methods to improve water infiltration, especially for small farmers who do not have the resources to implement more costly corrective measures. Unfortunately, in many instances, the small farmers use crop residues for other purposes and little, if any, is returned to the soil.

Crop residues left on the soil or worked into a rough cloddy soil surface will improve water penetration on sodic soils and will also improve water penetration into soils being irrigated by high SAR or low salinity water. Both crop residue left on the soil surface as well as the root system of the crop help in keeping the soil open. The benefits decline with time until replenished at the next cropping season.

The more fibrous and less easily decomposed crop residues, as from barley, rice, wheat, maize and sorghum, have improved water penetration, whereas residues from legumes and vegetable crops generally have not. The best residues are those which do not decompose or break down rapidly. These keep the soil porous by maintaining open channels and voids which improve water penetration. To be effective, relatively large quantities of residues are needed; for instance, manure has been used at rates of 40 to 400 metric tons per hectare to improve water infiltration. An organic application in the range of 10– 30 percent by soil volume in the upper 15 cm of soil may be needed to be effective.

Where water quality is affecting water infiltration, and organics are being tried to improve infiltration, it is important to incorporate the residues into the surface few centimetres of soil. Deeper incorporation is beneficial for soil structure and deeper percolation of applied water, but for infiltration problems caused by water quality, it is the surface soil that usually controls the depth of water entering the soil in a given period of time.

Rice hulls, sawdust, shredded bark, and many other waste products have been used in large volumes but with varying degrees of success. Tests with rice hulls in India increased the yield of rice in the first cropping season but yields reverted to their original level when the treatment was discontinued. From a long-term standpoint, the return of organic matter to the soil helps maintain soil structure and returns needed nutrients, but using a high rate of organic matter also causes problems. These include nutritional upsets, salinity effects caused by salty manure, nitrogen shortages or excesses owing to the use of certain types of materials (manures vs sawdust) and toxicities (chloride and potassium toxicities from rice hulls).

3.2.5 Irrigation Management

Physical and chemical methods in combination have proved to be the most effective approaches to solving water infiltration problems. However, these require extensive and continuing annual investment in both time and money to be effective. Many users try to complement these methods with irrigation practices to make the water infiltration problem easier to solve or manage. Several practices are discussed here.

i. Irrigating more frequently is a simple and effective approach especially for soils having an initially high infiltration rate but for which the rate drops rather quickly due to low salinity or high SAR. The objective is to supply the crop with adequate water at all times without secondary problems developing (waterlogging, poor aeration).

   Irrigating more frequently maintains a higher average soil water content and reduces the possibility of a water stress that might result if irrigations were spaced further apart. If the crop is not stressed for water between irrigations, increasing the irrigation frequency does little good.

ii. Pre-plant irrigation can be relied upon to fill the rooting depth to field capacity at a time when there is little chance of causing crop damage. In some difficult soils a pre-plant irrigation is the only opportunity to wet the deeper part of the crop root zone. It is also an effective method for wetting soils with a very slow infiltration rate.

iii. Extending the duration of an irrigation applies more water and is beneficial provided that soil aeration, waterlogging, runoff and surface drainage problems do not result. Many irrigators try to extend the irrigation by reducing the volume of flow to a field and holding the water on the field for a greater period of time. Careful management and monitoring is needed to maintain water use efficiency and to keep runoff to a minimum. Excessive runoff is frequently collected in a pond at the low side of the irrigated field and is pumped back up slope through a pipeline to be re-circulated into the irrigation stream. These recirculation (return-flow) systems are becoming common in surface irrigated areas and

can aid greatly in efficiently irrigating a soil with a low infiltration rate. In a few instances this system is installed following a comprehensive land levelling or grading programme to improve water use efficiency. By collecting and re-circulating water, both the total water use efficiency and depth of penetration can be more easily controlled.

iv. Changing irrigation systems may be necessary on more difficult soils. For instance, changing from a surface irrigation system to one which applies water more precisely (sprinklers for sandy soils and localized (drip) irrigation for heavier clayey soils) may allow the user to approach the soil intake rate more closely. These changes require large capital expenditures and additional power to operate, but the system can be designed to apply water at the rate desired. If runoff occurs with sprinklers or localized (drip) irrigation, the application rate is too high. Changing the rate of application after installation may be difficult and complete redesigning of the system may be needed. In some cases an existing sprinkler or localized irrigation system can be intermittently operated to match the infiltration rate more closely, stopping irrigation at the time runoff begins and re-irrigating every few hours until the desired depth of applied water is reached. This technique does allow the use of an existing sprinkler or localized irrigation system, but will probably use a little more water, thus increasing production cost, and it may also need more investment in equipment to offset idle time.

Sprinklers apply water in droplets, some quite large. On impact, these large droplets can disperse the soil surface particles and aggravate or cause an infiltration problem accompanied by excessive runoff. Application rates normally vary from 3 mm to 6 mm per hour over the irrigated area. Sprinklers are well adapted to sandy and loamy soils but less so to heavy or clayey type soils. Localized drip or trickle irrigation systems are better adapted to loamy or clayey soils and apply water through many small outlets (emitters) at a rate of 2 to 4 litres per hour. At these low rates they do not disperse the soil particles as do sprinklers. They are less well adapted to sandy soils.

4. TOXICITY PROBLEMS

4.1 SPECIFIC IONS AND THEIR EFFECTS

A toxicity problem is different from a salinity problem in that it occurs within the plant itself and is not caused by a water short-age. Toxicity normally results when certain ions are taken up with the soil-water and accumulate in the leaves during water transpiration to an extent that results in damage to the plant. The degree of damage depends upon time, concentration, crop sensitivity and crop water use, and if damage is severe enough, crop yield is reduced. The usual toxic ions in irrigation water are chloride, sodium and boron. Damage can be caused by each, individually or in combination.

Not all crops are equally sensitive to these toxic ions. Most annual crops are not sensitive at the concentrations shown in Table 1 but the majority of tree crops and woody perennial-type plants are. Toxicity symptoms, however, can appear on almost any crop if concentrations are high enough. Toxicity often accompanies or complicates a salinity or infiltration problem although it may appear even when salinity is low.

The toxic ions sodium and chloride can also be absorbed directly into the plant through the leaves moistened during sprinkler irrigation. This occurs typically during periods of high temperature and low humidity. The leaf absorption speeds the rate of accumulation of a toxic ion and may be a primary source of the toxicity.

Many trace elements, in addition to sodium, chloride and boron, are toxic to plants at very low concentrations. Fortunately most irrigation supplies contain very low concentrations of these trace elements and are generally not a problem. Suggested maximum concentrations for these unusual trace elements are given in Section 5.5. These concentrations are based upon limits established to protect the soil resource from contamination if continuously irrigated with water which contains them.

4.1.1 Chloride

The most common toxicity is from chloride in the irrigation water. Chloride is not adsorbed or held back by soils, therefore it moves readily with the soil-water, is taken up by the crop, moves in the transpiration stream, and accumulates in the leaves. If the chloride concentration in the leaves exceeds the tolerance of the crop, injury symptoms develop such as leaf burn or drying of leaf tissue. Normally, plant injury occurs first at the leaf tips (which is common for chloride toxicity), and progresses from the tip back along the edges as severity increases. Excessive necrosis (dead tissue) is often accompanied by early leaf drop or defoliation. With sensitive crops, these symptoms occur when leaves accumulate from 0.3 to 1.0 percent chloride on a dry weight basis, but sensitivity varies among these crops. Many tree crops, for example, begin to show injury above 0.3 percent chloride (dry weight).

Chemical analysis of plant tissue is commonly used to confirm a chloride toxicity. The part of the plant generally used for analysis varies with the crop, depending upon which of the available interpretative values is being followed. Leaf blades are most often used, but the petioles of some crops (grapes) are sometimes used rather than leaves. For irrigated areas, the chloride uptake depends not only on the water quality but also on the soil chloride, controlled by the amount of leaching that has taken place and the ability of the crop to exclude

chloride. Crop tolerances to chloride are not nearly so well documented as crop tolerances to salinity. Table 14 gives the known tolerances of several crops to chloride in the saturation extract or in the applied water. These values may need to be changed where local experience indicates that different levels cause damage. For example, tobacco, although tolerant to chloride, acquires progressively more undesirable burning characteristics of the leaf as well as reduced storage life if chloride levels in irrigation water increase above a few milliequivalents per litre. This greatly affects its market value.

Table 14 CHLORIDE TOLERANCE OF SOME FRUIT CROP CULTIVARS AND ROOTSTOCKS[1]

Crop	Rootstock or Cultivar	Maximum Permissible Cl^- without Leaf Injury[2]	
		Root Zone (Cl_e) (me/l)	Irrigation Water (Cl_w)[3] [4] (me/l)
	Rootstocks		
Avocado *(Persea americana)*	West Indian	7.5	5.0
	Guatemalan	6.0	4.0
	Mexican	5.0	3.3
Citrus *(Citrus spp.)*	Sunki Mandarin	25.0	16.6
	Grapefruit		
	Cleopatra mandarin		
	Rangpur lime		
	Sampson tangelo	15.0	10.0
	Rough lemon		
	Sour orange		
	Ponkan mandarin		
	Citrumelo 4475	10.0	6.7
	Trifoliate orange		
	Cuban shaddock		
	Calamondin		
	Sweet orange		
	Savage citrange		
	Rusk citrange		
	Troyer citrange		
Grape *(Vitis spp.)*	Salt Creek, 1613-3	40.0	27.0
	Dog Ridge	30.0	20.0
Stone Fruits *(Prunus spp.)*	Marianna	25.0	17.0
	Lovell, Shalil	10.0	6.7
	Yunnan	7.5	5.0
	Cultivars		
Berries *(Rubus spp.)*	Boysenberry	10.0	6.7
	Olallie blackberry	10.0	6.7
	Indian Summer Raspberry	5.0	3.3
Grape *(Vitis spp.)*	Thompson seedless	20.0	13.3
	Perlette	20.0	13.3
	Cardinal	10.0	6.7
	Black Rose	10.0	6.7

Strawberry *(Fragaria spp.)*	Lassen	7.5	5.0
	Shasta	5.0	3.3

[1] Adapted from Maas (1984).

[2] For some crops, the concentration given may exceed the overall salinity tolerance of that crop and cause some reduction in yield in addition to that caused by chloride ion toxicities.

[3] Values given are for the maximum concentration in the irrigation water. The values were derived from saturation extract data (EC_e) assuming a 15–20 percent leaching fraction and $EC_e = 1.5\ EC_w$.

[4] The maximum permissible values apply only to surface irrigated crops. Sprinkler irrigation may cause excessive leaf burn at values far below these (see Section 4.3).

A chloride toxicity can occur by direct leaf absorption through leaves wet during overhead sprinkler irrigation. This occurs most frequently with the rotating type sprinkler heads and is discussed in Section 4.3.

4.1.2 Sodium

Sodium toxicity is not as easily diagnosed as chloride toxicity, but clear cases of the former have been recorded as a result of relatively high sodium concentrations in the water (high Na or SAR). Typical toxicity symptoms are leaf burn, scorch and dead tissue along the outside edges of leaves in contrast to symptoms of chloride toxicity which normally occur initially at the extreme leaf tip. An extended period of time (many days or weeks) is normally required before accumulation reaches toxic concentrations. Symptoms appear first on the older leaves, starting at the outer edges and, as the severity increases, move progressively inward between the veins toward the leaf centre. Sensitive crops include deciduous fruits, nuts, citrus, avocados and beans, but there are many others. For tree crops, sodium in the leaf tissue in excess of 0.25 to 0.50 percent (dry weight basis) is often associated with sodium toxicity.

Leaf tissue analysis is commonly used to confirm or monitor sodium toxicity but a combination of soil, water and plant tissue analyses greatly increases the probability of a correct diagnosis. When using only leaf blade analysis to diagnose sodium toxicity, it is advisable to include analyses of leaf blades from damaged trees as well as separate analyses from nearby undamaged ones for comparative purposes.

Sodium toxicity is often modified or reduced if sufficient calcium is available in the soil. Whether an indicated sodium toxicity is a simple one or is more complicated involving a possible calcium deficiency or other interaction is presently being researched. Preliminary results indicate that for at least a few annual crops, calcium deficiency rather than sodium toxicity may be occurring. If confirmed, these crops should respond to calcium fertilization using material such as gypsum or calcium nitrate. For a discussion of possible calcium deficiency, see Section 5.6 on Nutrition and Water Quality.

Many crops do show sodium toxicity. The toxicity guidelines of Table 1 use SAR as the indicator of the potential for a sodium toxicity problem which is expected to develop following surface irrigation with a particular quality of water. Table 15 gives the relative sodium tolerance of several representative crops. The data in the table are given not in terms of SAR but of soil exchangeable sodium (ESP). Estimates of soil ESP that are expected to result from long-term (several years) use of water of given SAR can be made using the nomogram in Figure 1. (Refer to Section 3.2.1 for a discussion of the impact of erroneous interpretations of SAR-ESP relationships in presence of gypsum.)

Table 15 RELATIVE TOLERANCE OF SELECTED CROPS TO EXCHANGEABLE SODIUM[1]

Sensitive[2]	Semi-tolerant[2]	Tolerant[2]
Avocado	**Carrot**	**Alfalfa**
(Persea americana)	*(Daucus carota)*	*(Medicago sativa)*
Deciduous Fruits	**Clover, Ladino**	**Barley**
Nuts	*(Trifolium repens)*	*(Hordeum vulgare)*
Bean, green	**Dallisgrass**	**Beet, garden**
(Phaseolus vulgaris)	*(Paspalum dilatatum)*	*(Beta vulgaris)*
Cotton (at germination)	**Fescue, tall**	**Beet, sugar**
(Gossypium hirsutum)	*(Festuca arundinacea)*	*(Beta vulgaris)*
Maize	**Lettuce**	**Bermuda grass**
(Zea mays)	*(Lactuca sativa)*	*(Cynodon dactylon)*
Peas	**Bajara**	**Cotton**
(Pisum sativum)	*(Pennisetum typhoides)*	*(Gossypium hirsutum)*
Grapefruit	**Sugarcane**	**Paragrass**
(Citrus paradisi)	*(Saccharum officinarum)*	*(Brachiaria mutica)*
Orange	**Berseem**	**Rhodes grass**
(Citrus sinensis)	*(Trifolium alexandrinum)*	*(Chloris gayana)*
Peach	**Benji**	**Wheatgrass, crested**
(Prunus persica)	*(Melilotus parviflora)*	*(Agropyron cristatum)*
Tangerine	**Raya**	**Wheatgrass, fairway**
(Citrus reticulata)	*(Brassica juncea)*	*(Agropyron cristatum)*
Mung	**Oat**	**Wheatgrass, tall**
(Phaseolus aurus)	*(Avena sativa)*	*(Agropyron elongatum)*
Mash	**Onion**	**Karnal grass**
(Phaseolus mungo)	*(Allium cepa)*	*(Diplachna fusca)*
Lentil	**Radish**	
(Lens culinaris)	*(Raphanus sativus)*	
Groundnut (peanut)	**Rice**	
(Arachis hypogaea)	*(Oryza sativus)*	
Gram	**Rye**	
(Cicer arietinum)	*(Secale cereale)*	
Cowpeas	**Ryegrass, Italian**	
(Vigna sinensis)	*(Lolium multiflorum)*	
	Sorghum	
	(Sorghum vulgare)	
	Spinach	
	(Spinacia oleracea)	
	Tomato	
	(Lycopersicon esculentum)	
	Vetch	
	(Vicia sativa)	
	Wheat	

	(Triticum vulgare)	

Adapted from data of FAO-Unesco (1973); Pearson (1960); and Abrol (1982).

The approximate levels of exchangeable sodium percentage (ESP) corresponding to the three categories of tolerance are: sensitive less than 15 ESP; semi-tolerant 15–40 ESP; tolerant more than 40 ESP. Tolerance decreases in each column from top to bottom. The tolerances listed are relative because, usually, nutritional factors and adverse soil conditions stunt growth before reaching these levels. Soil with an ESP above 30 will usually have too poor physical structure for good crop production. Tolerance in most instances were established by first stabilizing soil structure.

Particular care in assessment of a potential toxicity due to SAR or sodium is needed with high SAR water because apparent toxic effects of sodium may be due to or complicated by poor water infiltration. As shown in Table 15, only the more sensitive perennial crops have yield losses due to sodium if the physical condition of the soil remains good enough to allow adequate infiltration. Several of the crops listed as more tolerant do show fair growth when soil structure is maintained and, in general, these crops can withstand higher ESP levels if the soil structure and aeration can be maintained, as in coarse textured soils.

4.1.3 Boron

Boron, unlike sodium, is an essential element for plant growth. (Chloride is also essential but in such small quantities that it is frequently classed non-essential.) Boron is needed in relatively small amounts, however, and if present in amounts appreciably greater than needed, it becomes toxic. For some crops, if 0.2 mg/l boron in water is essential, 1 to 2 mg/l may be toxic. Surface water rarely contains enough boron to be toxic but well water or springs occasionally contain toxic amounts, especially near geothermal areas and earthquake faults. Boron problems originating from the water are probably more frequent than those originating in the soil. Boron toxicity can affect nearly all crops but, like salinity, there is a wide range of tolerance among crops.

Boron toxicity symptoms normally show first on older leaves as a yellowing, spotting, or drying of leaf tissue at the tips and edges. Drying and chlorosis often progress toward the centre between the veins (interveinal) as more and more boron accumulates with time. On seriously affected trees, such as almonds and other tree crops which do not show typical leaf symptoms, a gum or exudate on limbs or trunk is often noticeable.

Most crop toxicity symptoms occur after boron concentrations in leaf blades exceed 250–300 mg/kg (dry weight) but not all sensitive crops accumulate boron in leaf blades. For example, stone fruits (peaches, plums, almonds, etc.), and pome fruits (apples, pears and others) are easily damaged by boron but they do not accumulate sufficient boron in the leaf tissue for leaf analysis to be a reliable diagnostic test. With these crops, boron excess must be confirmed from soil and water analyses, tree symptoms and growth characteristics.

A wide range of crops was tested for boron tolerance by using sand-culture techniques (Eaton 1944). Previous boron tolerance tables in general use have been based for the most part on these data. These tables reflected boron tolerance at which toxicity symptoms were first observed and, depending on crop, covered one to three seasons of irrigation. The original data from these early experiments, plus data from many other sources, have recently been reviewed (Maas 1984). Table 16 presents this recent revision of the data. It is not based on plant symptoms, but upon a significant loss in yield to be expected if the indicated boron value is exceeded. Table 17 presents recent data on citrus and stone fruit rootstocks and are listed in order of increasing boron accumulation.

4.2 MANAGEMENT OF TOXICITY PROBLEMS

Obviously, the most effective method to prevent occurrence of a toxicity problem is to choose an irrigation water that has no potential to develop a toxicity. But if such water is not available, there are often management options than can be adopted to reduce toxicity and improve yields.

Table 16 RELATIVE BORON TOLERANCE OF AGRICULTURAL CROPS [1,2]

Very Sensitive (<0.5 mg/l)	
Lemon	*Citrus limon*
Blackberry	*Rubus spp.*
Sensitive (0.5 – 0.75 mg/l)	
Avocado	*Persea americana*
Grapefruit	*Citrus X paradisi*
Orange	*Citrus sinensis*
Apricot	*Prunus armeniaca*
Peach	*Prunus persica*
Cherry	*Prunus avium*
Plum	*Prunus domestica*
Persimmon	*Diospyros kaki*
Fig, kadota	*Ficus carica*
Grape	*Vitis vinifera*
Walnut	*Juglans regia*
Pecan	*Carya illinoiensis*
Cowpea	*Vigna unguiculata*
Onion	*Allium cepa*
Sensitive (0.75 – 1.0 mg/l)	
Garlic	*Allium sativum*
Sweet potato	*Ipomoea batatas*
Wheat	*Triticum eastivum*
Barley	*Hordeum vulgare*
Sunflower	*Helianthus annuus*
Bean, mung	*Vigna radiata*
Sesame	*Sesamum indicum*
Lupine	*Lupinus hartwegii*
Strawberry	*Fragaria spp.*
Artichoke, Jerusalem	*Helianthus tuberosus*
Bean, kidney	*Phaseolus vulgaris*
Bean, lima	*Phaseolus lunatus*
Groundnut/Peanut	*Arachis hypogaea*
Moderately Sensitive (1.0 – 2.0 mg/l)	
Pepper, red	*Capsicum annuum*
Pea	*Pisum sativa*
Carrot	*Daucus carota*

Radish	*Raphanus sativus*
Potato	*Solanum tuberosum*
Cucumber	*Cucumis sativus*
Moderately Tolerant (2.0 – 4.0 mg/l)	
Lettuce	*Lactuca sativa*
Cabbage	*Brassica oleracea capitata*
Celery	*Apium graveolens*
Turnip	*Brassica rapa*
Bluegrass, Kentucky	*Poa pratensis*
Oats	*Avena sativa*
Maize	*Zea mays*
Artichoke	*Cynara scolymus*
Tobacco	*Nicotiana tabacum*
Mustard	*Brassica juncea*
Clover, sweet	*Melilotus indica*
Squash	*Cucurbita pepo*
Muskmelon	*Cucumis melo*
Tolerant (4.0 – 6.0 mg/l)	
Sorghum	*Sorghum bicolor*
Tomato	*Lycopersicon lycopersicum*
Alfalfa	*Medicago sativa*
Vetch, purple	*Vicia benghalensis*
Parsley	*Petroselinum crispum*
Beet, red	*Beta vulgaris*
Sugarbeet	*Beta vulgaris*
Very Tolerant (6.0 – 15.0 mg/l)	
Cotton	*Gossypium hirsutum*
Asparagus	*Asparagus officinalis*

[1] Data taken from Maas (1984).

[2] Maximum concentrations tolerated in soil-water or saturation extract without yield or vegetative growth reductions. Boron tolerances vary depending upon climate, soil conditions and crop varieties. Maximum concentrations in the irrigation water are approximately equal to these values or slightly less.

Table 17 CITRUS AND STONE FRUIT ROOTSTOCKS LISTED IN ORDER OF INCREASING BORON ACCUMULATION AND TRANSPORT TO LEAVES[1]

Common Name	Botanical Name	Level of Boron accumulation
Citrus		
Alemow	*Citrus macrophylla*	Low
Gajanimma	*Citrus pennivesiculata or Citrus moi*	
Chinese box orange	*Severinia buxifolia*	
Sour orange	*Citrus aurantium*	
Calamondin	*X Citrofortunella mitis*	
Sweet orange	*Citrus sinensis*	

Yuzu	*Citrus junos*	
Rough lemon	*Citrus limon*	
Grapefruit	*Citrus X paradisi*	
Rangpur lime	*Citrus X limonia*	
Troyer citrange	*X Citroncirus webberi*	
Savage citrange	*X Citroncirus webberi*	
Cleopatra mandarin	*Citrus reticulata*	
Rusk citrange	*X Citroncirus webberi*	
Sunki mandarin	*Citrus reticulata*	
Sweet lemon	*Citrus limon*	
Trifoliate orange	*Poncirus trifoliata*	
Citrumelo 4475	*Poncirus trifoliata X citrus paradisi*	
Ponkan mandarin	*Citrus reticulata*	
Sampson tangelo	*Citrus X tangelo*	
Cuban shaddock	*Citrus maxima*	
Sweet lime	*Citrus aurantiifolia*	High
	Stone Fruit	
Almond	*Prunus dulcis*	Low
Myrobalan plum	*Prunus cerasifera*	
Apricot	*Prunus armeniaca*	
Marianna plum	*Prunus domestica*	
Shalil peach	*Prunus persica*	High

[1] Data taken from Maas (1984).

The potentially toxic ions sodium, chloride and boron can each be reduced by leaching in a manner similar to that for salinity, but the depth of water required varies with the toxic ion and may in some cases become excessive. If leaching becomes excessive, many growers change to a more tolerant crop. Increasing the leaching or changing crops in an attempt to live with the higher levels of toxic ions may require extensive changes in the farming system. In cases where the toxicity problem is not too severe, relatively minor changes in farm cultural practices can minimize the impact. In a few cases, an alternative water supply may be available to blend with a poorer supply to lower the hazard from the poorer one.

Alternatives for management of toxicity and to maintain production are discussed in the following sections.

4.2.1. Leaching

A parallel can be drawn between salinity and toxicity. The toxic ions (chloride, sodium and to a lesser extent boron) are an appreciable part of the normal salinity accumulation in the root zone and, as with salinity, leaching is the only practical way to reduce and control these toxic ions in the crop root zone. A toxicity can develop within a few irrigations or within one or more growing seasons, depending upon the toxic ion concentrations in the irrigation water and the leaching fraction accomplished.

Leaching can be used either to prevent a problem or to correct the problem after it has been recognized from plant symptoms or damage to the crop. Plant symptoms along with soil, plant

and water analyses are very useful for monitoring for both potential toxicity and the adequacy of present leaching practices and crop management. If the toxic ion is coming from the irrigation water, emphasis should be placed on prevention through adequate leaching. In continuously irrigated areas, reclamation should not be necessary unless leaching has been inadequate and excess toxic ions have built up to concentrations that affect crop production.

Chloride ions move readily in the applied irrigation water and make up an important part of water and soil salinity. The concentration factors for salinity given in Table 4 also apply for the chloride ion. The concentration factor for a certain leaching fraction (Table 3) multiplied by the concentration of the chloride ion in the water will closely approximate the expected average concentration in the crop root zone. Chloride can be leached and the leaching requirement equation (9) for salinity (Rhoades 1974), as described in Section 2.4.2, is equally appropriate for calculating the leaching requirement for chloride if the chloride tolerance (Cle in saturation extract) and the chloride in the irrigation water (Clw) are known. The LR equation then becomes:

$$LR_{(Cl)} = \frac{Cl_w}{5\ Cl_e - Cl_w} \qquad (17)$$

where: $LR_{(Cl)}$ = the minimum leaching requirement needed to control chloride with ordinary surface methods of irrigation

Cl_w = chloride concentration in the applied irrigation water in milliequivalents per litre (me/l)

Cl_e = chloride concentration tolerated by crop as determined in the soil saturation extract, in milliequivalents per litre (me/l)

Sodium ions cause toxicities to sodium sensitive crops (mostly tree crops and woody ornamentals) at a lower SAR value than would be expected to cause a permeability problem. The sodium ions move less readily with the soil-water than do chlorides. However, research indicates that high leaching fractions (LF) can be effective to maintain a low soil SAR but for SAR values in the water in excess of 9, without added amendments, a leaching fraction of 0.30 or greater may be required. Deliberately adding such large quantities of water in an attempt to control sodium toxicity may not be practical because this may cause problems with soil aeration and drainage. A preferred solution is to add moderate amounts of gypsum or calcium supplying fertilizer materials (acidifying if lime is present; basic or calcium supplying if no soil lime is present). If leaching plus amendments cannot control the sodium toxicity problem, a change to a more tolerant crop may be advisable.

Boron is much more difficult to leach than are chloride and sodium. Boron moves slowly with the soil-water and requires about three times as much leaching water as would be needed to reduce an equivalent amount of chloride or salinity. In many field observations, the boron concentration in the soil saturation extract of the upper root zone usually approaches that in the irrigation water applied. With good irrigation management, it should be possible to reduce and maintain the upper root zone soil at nearly the same boron concentration as in the applied water.

As discussed above, the key to controlling a toxicity problem is to select a good source of irrigation water and then leach as needed to control any toxic build-up which may impair crop production. If the irrigation management is poor and harmful concentrations develop, amendments and reclamation leaching may be needed to restore soil productivity. For reclamation leaching, the same general guides apply for both salinity and chloride (see Section 2.4.6). For boron, the same principles apply but about three times as much water will be needed. Figure 22 shows the relative effectiveness of leaching of boron by sprinklers or by intermittent ponding. Recent research indicates that soil application of sulphuric acid may

speed reclamation of a boron affected soil but no extensive field tests or observations are available to confirm this.

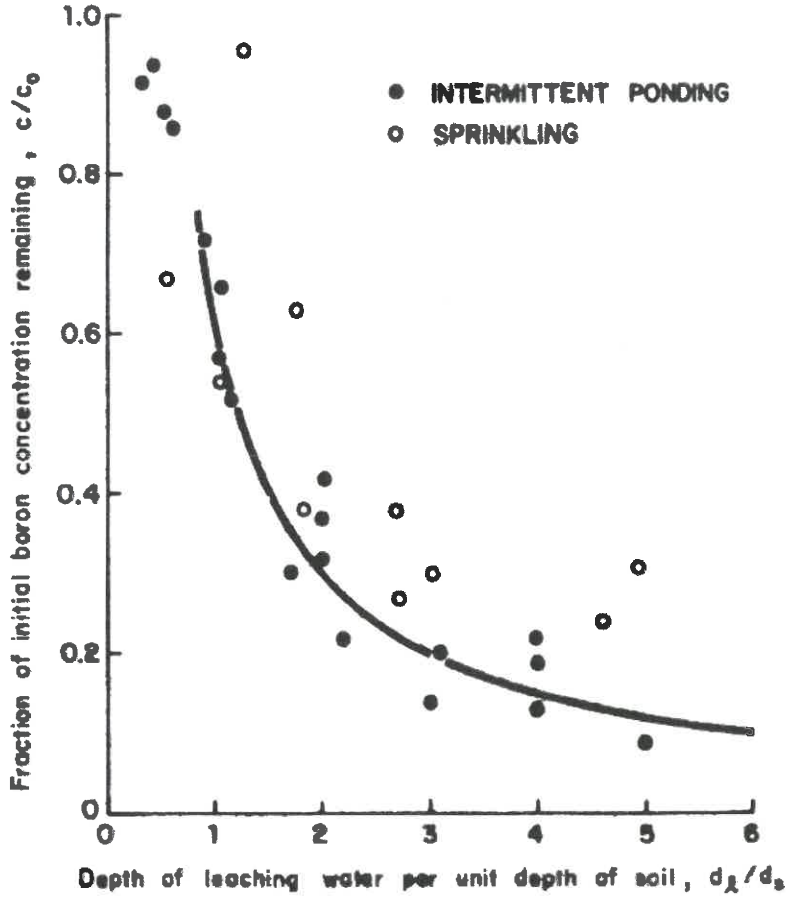


Fig. 22 Depth of leaching water per unit depth of soil required to reclaim a soil inherently high in boron (Hoffman 1980)

4.2.2. Crop Selection

Selecting a more tolerant crop offers a very practical solution to a toxicity problem. There are degrees of sensitivity to boron, chloride and sodium just as there are degrees of sensitivity to salinity. Limited information is available on the relative tolerance of crops to toxic ions. Table 14 presents data for chloride, Table 15 for sodium, and Tables 16 and 17 for boron. It must be kept in mind that these are approximations and local farming conditions may modify them. Factors affecting tolerance include climate, irrigation management, leaching fraction, drainage, growth stage of the crop and crop maturity date.

The selection of tolerant rootstocks or cultivars is another method of changing the crop to cope with the existing conditions. Certain rootstocks or varieties differ in their ability to exclude ions such as chloride (see Table 14) or boron (see Table 17) and produce good crops under less than ideal conditions.

4.2.3 Cultural Practices

Since leaching is the principal method of toxic ion control, cultural practices to aid in management of irrigation water at the farm level are the keys to success. Cultural practices

which offer better control and distribution of water include land grading, profile modification and artificial drainage if natural drainage is inadequate. These steps are complementary to those previously discussed for improved salinity and toxicity control.

The severity of a toxicity problem will increase as the crop withdraws soil-water and the soil dries between irrigations (Figure 4). The ions become concentrated in the smaller volume of soil-water. As the upper soil dries, the crop must withdraw more and more of its water needs from the deeper soil where salinity and toxic ions are usually in greater concentration. Increasing the frequency of irrigation supplies a greater proportion of the water needs from the upper soil as well as diluting the deeper soil-water and should reduce the impact of both salinity and toxic ions. This has been previously discussed in Section 2.4.4.

Fertilization practices are normally thought to offer little benefit to counter salinity, but for a toxicity such as that from boron in a citrus crop, many growers are applying extra nitrogen to stimulate vegetative growth. Boron first accumulates to toxic amounts in the older leaves which then become necrotic and drop, thereby reducing the photosynthetic capability of the tree. In this case, nitrogen is used to stimulate new growth to restore the leaf area and photosynthetic capability. Leaf analysis for nitrogen is the guide to the nitrogen requirement. For example, the recommended nitrogen guideline for the Washington Navel Orange is 2.4–2.6 percent nitrogen (dry weight) in 5 to 7-month old terminal spring cycle leaves from non-fruiting, nonflushing shoots. But, if boron becomes a problem, this guideline is raised to nearer to 2.7–2.8 percent N and fertilization practices are modified to reach it.

It takes time to accumulate boron in the leaves. A crop like walnuts may not accumulate sufficient quantities from moderate amounts of boron (1 to 2 mg/l) in the water to damage the crop before it is harvested. In such a case, toxicity is a potential threat and by the end of the season most leaves will show severe boron toxicity (B = 1500 mg/kg). Even though the quality of crop is not greatly affected, the tree vigour and size may be. Alfalfa grown in the Clear Lake area of California using relatively high boron water (> 10 mg/l) is apparently cut frequently enough to avoid recognizeable problems; similarly, golf course greens at Calistoga, California, irrigated with high boron wastewater (2 to 3 mg/l) have not shown toxicity symptoms, presumably for the same reason (see Section 8.25).

Sodium toxicity (high SAR) from applied water is generally countered by use of a soil or water amendment such as gypsum. In general, where salinity of water is relatively low (ECw < 0.5 ds/m), the beneficial response to a water-applied amendment is much greater than if salinity is high because it is far easier to change the sodium to calcium ratio of a relatively low salinity water than one of higher salinity. Soil amendments rather than water amendments are relied upon to correct a sodium problem related to a highly saline water or to a high ESP soil. It also becomes more difficult to correct the sodium toxicity as the soil clay content increases. Using amendments should not be expected to mitigate chloride or boron problems, unless the amendment improves water infiltration and soil permeability which would permit increased leaching to take place. Amendments are discussed in more detail in Section 3.2.1.

4.2.4 Blending Water Supplies

If an alternative water supply is available, but not fully adequate in quantity or quality, a blend of waters may offer an overall improvement in quality and reduce the potential toxicity problem. Blending is especially effective for a sodium toxicity problem since proportions of monovalent (Na^+) and divalent (Ca^{++}) cations absorbed on the soil depend on concentration, with dilution favouring adsorption of the divalent calcium and magnesium ions rather than the monovalent sodium. A discussion of a quality change resulting from blending is given in Section 2.4.7 and Section 3.2.2.

4.3 TOXICITY EFFECTS DUE TO SPRINKLER IRRIGATION

Overhead sprinkling of sensitive crops can cause toxicities not encountered when irrigating by surface methods. The toxicity occurs due to excess quantities of sodium and chloride from the irrigation water being absorbed through leaves wet by the sprinklers. Extreme cases have resulted in severe leaf burn and defoliation. Absorption and toxicity occur mostly during periods of high temperature and low humidity (<30 percent), frequently aggravated by windy conditions. Rotating sprinkler heads present the greatest risk. Between rotations water evaporates and the salts become more concentrated in the shrinking volume of water. Slowly rotating sprinklers (less than 1 revolution per minute) cause alternate wetting and drying cycles; the slower the speed of rotation, the greater the absorption. High frequency (near daily) spray irrigation has also created problems in some cases.

The leaf burn and resulting crop damage seems to be due to uptake from the applied water of either sodium or chloride. In some instances both sodium and chloride have been absorbed and both accumulate. Toxicity to sensitive crops occurs at relatively low sodium or chloride concentrations (> 3 me/l) and, in general, crops sensitive to sodium or chloride are thought to be most sensitive to foliar absorption. Most annual crops are not sensitive but they will be damaged if concentrations are high enough. Crop tolerances to sodium and chloride in sprinkler-applied irrigation water are not well established due to limited data and the pronounced influence of climatic conditions, but Table 18 gives estimates based upon recent field investigations. They should be used as a first approximation of the potential hazard and any situation which approaches the sodium or chloride values given should be further evaluated by field testing before full implementation of the application system.

Table 18 RELATIVE TOLERANCE OF SELECTED CROPS TO FOLLAR INJURY FROM SALINE WATER APPLIED BY SPRINKLERS [1,2]

Na^+ or Cl^- concentrations causing foliar injury[3] me/l			
<5	5 – 10	10 – 20	>20
Almond	**Grape**	**Alfalfa**	**Cauliflower**
(Prunus dulcis)	*(Vitis spp.)*	*(Medicago sativa)*	*(Brassica oleracea botrytis)*
Apricot	**Pepper**	**Barley**	**Cotton**
(Prunus armeniaca)	*(Capsicum annuum)*	*(Hordeum vulgare)*	*(Gossypium hirsutum)*
Citrus	**Potato**	**Corn (maize)**	**Sugarbeet**
(Citrus sp.)	*(Solanum tuberosum)*	*(Zea mays)*	*(Beta vulgaris)*
Plum	**Tomato**	**Cucumber**	**Sunflower**
(Prunus domestica)	*(Lycopersicon lycopersicum)*	*(Cucumis sativus)*	*(Helianthus annuus)*
		Safflower	
		(Carthamus tinctorius)	
		Sesame	
		(Sesamum indicum)	
		Sorghum	
		(Sorghum bicolor)	

[1] Data taken from Maas (1984).

[2] Susceptibility based on direct accumulation of salts through the leaves.

[3] Leaf absorption and foliar injury are influenced by cultural and environmental conditions such as drying winds, low humidity, speed of rotation of sprinklers,and the timing and frequency of irrigations. Data presented are only general guidelines for late spring and summer daytime sprinkling.

Toxicity has occurred in California citrus areas on leaves wet by sprinklers with water at concentrations as low as 3 me/l of either sodium or chloride. With furrow and flood irrigation this same water causes no toxicity or leaf burn. Slight damage has been reported on alfalfa using water with ECw = 1.35 ds/m and 6 me/l sodium and 7 me/l chloride, but this was under high evaporative, possibly windy conditions, using rotating sprinklers (Table 19). In contrast, water as high as ECw = 4.4 ds/m with 24 me/l sodium and 37 me/l chloride showed little or no damage when evaporative conditions were low (Table 20). The sensitivity also depends upon the crop. Several vegetable crops tested were fairly insensitive to foliar effects even at very high concentrations and in semi-arid areas.

Foliage can be damaged by salt from ocean spray or from drift from sprinklers accumulating on the leaf surface. This has occurred along the Pacific Coast of California as well as in downwind drift areas from sprinklers. Other less frequent problems also occurring with sprinklers include reddish deposits on leaves due to iron content of the sprinkler-applied water and white deposits from bicarbonate or other deposits from water solubles such as gypsum. While these are not toxicities, they can reduce the marketability of a foliage crop or the acceptability of a crop such as table grapes (see Section 5.3).

Where foliar absorption or deposition is a problem, certain management practices have been successful to counter it. Each particular problem will need to be evaluated separately. Some practices may require minor changes in management while others will require more elaborate alterations including holding reservoirs or replacing the irrigation system.

Table 19 LEAF BURN ON ALFALFA WITH THREE RATES OF WATER APPLICATION BY SPRINKLER IRRIGATION IN IMPERIAL VALLEY, CALIFORNIA [1,2]

	Rate of Application (mm/hr)		
	1.8	2.7	4.0
Alfalfa plants with leaf burn (percent)	92.5	5.0	2.5

[1] Data taken from Robinson (1980).

[2] Irrigation water quality ECw = 1.35 dS/m
TDS = 875 mg/l
Na = 6 me/l
Cl = 7 me/l

Table 20 SODIUM CONTENT IN COTTON LEAVES IN PERCENT OVEN DRY WEIGHT [1,2]

Variety	Day Sprinkled	Night Sprinkled	Surface Irrigated
Short staple	0.73	0.46	0.44
Long staple	0.29	0.12	0.10

[1] Data taken from Busch and Turner (1967).

[2] Irrigation water quality ECw = 4.4 dS/m

Na = 24 me/l

Irrigate at night: Night sprinkling is quite effective in reducing or eliminating both sodium and chloride toxicity due to foliar absorption and has also reduced the problem of foliar deposits. As humidity generally rises at night and winds decrease, the rate of evaporation and concentration is reduced. Night irrigation has also been of benefit by lowering night-time temperatures during very hot periods. Table 20 shows differences in sodium content in cotton leaves when night and daytime sprinkler irrigation were compared.

Avoid periods of high wind: Hot, dry winds are a major factor in the concentration, absorption and deposition. Avoiding these periods for overhead sprinkling minimizes the problem and avoids possible leaf burn caused by drift to downwind crop areas. In some areas, this may require night irrigation.

Control sprinkler drift: In hot, windy areas, the downwind drift from sprinkler irrigation presents a risk. This drift, if it lands on adjacent plant leaves, is more concentrated than the applied sprinkler water. To minimize the potential leaf burn, movable sprinklers should be moved progressively downwind rather than upwind in order to wash away drifted salts as soon as possible. To avoid drift during high risk periods requires sprinkling during early morning, late evening and night hours when the winds are likely to be less than in the middle of the day. Mist nozzles or high pressure impact sprinklers should be avoided in windy areas where drift is likely to be a problem. Grouping sprinklers in blocks is preferable to long widely spaced single rows if drift is likely to be a problem.

Increase sprinkler rotation speeds: Slowly rotating sprinklers allow appreciable drying on the leaves between sprinkler rotations. More frequent or continuous wetting of foliage allows less drying of leaves and less absorption than intermittent wetting and drying. A sprinkler head rotation of one revolution per minute or less is often recommended, but to achieve this may involve changing the type of sprinkler head and, in some cases, the pressure and design of the system. This alternative may prove costly to implement if the same water use efficiency is to be maintained.

Increase rate of application: If soil water storage capacity and water infiltration rate permit, a higher rate of application may reduce damage by reducing the total period of crop wetting. This would reduce the severity of toxicity due to leaf absorption. Increasing the application rate can be accomplished by enlarging the sprinkler orifices, increasing the pressure, or reducing the spacing on the sprinkler system, but this might require a costly change in sprinkler system design. Table 19 shows the leaf burn associated with different rates of application for the Imperial Valley of California. The data indicate that application rates less than 2.7 mm/hr cause excessive amounts of leaf burn on alfalfa during the high evaporative demand (summer) period in this California desert climate (Robinson 1980).

Change irrigation method: Sprinkler systems which moisten only a little of the foliage can greatly reduce the absorption problem. Low angle or undertree sprinklers wet less of the leaves, but in many cases any lower leaves that are moistened still show symptoms from foliar absorption and in some cases the lower branches may be defoliated. A survey of citrus orchards in California showed that leaf burn and defoliation were associated with the lower leaves that had been wetted by sprinkler spray. Non-sprayed leaves from the upper portions of the trees and leaves from furrow-irrigated trees showed no leaf damage and markedly lower sodium content. In Bahrain (see Section 8.6), similar results have been shown with lemon trees. Furrow, flood, basin or drip irrigation are viable alternatives since they do not wet the leaves.

As demonstrated on some commercial farms in western USA, pivot irrigation sprinkler systems can be modified with drop lines to apply the water to the soil and not to the leaves for many crops.

Increase droplet size: Where a change in sprinkler system design is needed, sprinkler heads that apply a larger droplet size will result in less absorption as small droplets are more subject to evaporation and wind drift. While increasing droplet size may reduce the effect from foliar absorption, a further assessment needs to be made of the effect of droplet size on soil dispersion, sealing and compaction which could cause greater runoff.

Select different crops: In extreme cases it may be necessary to change from the more sensitive crops, such as beans and grapes, if they can no longer be economically produced. Local experience should provide a guide to crops more tolerant to the given conditions.

Plant during cooler seasons: Planting crops during the cooler part of the growing season reduces total water use and the hazards from sprinkler applied water. These cooler season crops can sometimes be harvested before periods of extremely low humidity. Crops planted in the cooler season have a better chance to mature before the sodium or chloride can accumulate to high enough concentrations to cause toxicity damage. Changing the growing season is an extreme alternative which should only be taken after assessment of the market possibilities for the new planting date.

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5. MISCELLANEOUS PROBLEMS

5.1 EXCESS NITROGEN

Nitrogen is a plant nutrient and stimulates crop growth. Natural soil nitrogen or added fertilizers are the usual sources, but nitrogen in the irrigation water has much the same effect as soil-applied fertilizer nitrogen and an excess will cause problems, just as too much fertilizer would. If excessive quantities are present or applied, production of several commonly grown crops may be upset because of over-stimulation of growth, delayed maturity or poor quality.

The most readily available forms of nitrogen are nitrate and ammonium but nitrate (NO_3 -N) occurs most frequently in irrigation water. Ammonium-nitrogen is seldom present in excess of 1 mg/l unless ammonia fertilizer or wastewater is being added to the water supply. The concentration in most surface and groundwater is usually less than 5 mg/l NO_3 -N but some unusual groundwater may contain quantities in excess of 50 mg/l. Drainage water from below the root zone frequently has higher levels of nitrogen due to deep leaching of fertilizers. Since nitrogen is present in so many water supplies, it is recommended that the nitrogen content of all irrigation water be monitored and the nitrogen present included as an integral part of the planned fertilization programme. Wastewater, especially from food processing and domestic sources, is known to be high in nitrogen with values ranging from 10 to 50 mg/l (1 mg/l NO_3-N = 1 kg N/1000 m^3 of water).

There are many ways of reporting nitrogen since it is combined in various organic and inorganic complexes. The most important factor for plants is the total amount of nitrogen (N) regardless of whether it is in the form of nitrate-nitrogen (NO_3-N), ammonium-nitrogen (NH_4-N) or organic-nitrogen (Org-N). By reporting in the form of nitrogen, comparisons can be made. For example, NO_3-N means nitrogen in the form of NO_3 while NH_4-N means nitrogen in the form of NH_4 reported as N in mg/l (10 mg/l N = 45 mg/l NO_3 = 13 mg/l NH_4, but each should be reported as 10 mg/l NO_3-N or 10 mg/l NH_4-N). In the guidelines of Table 1, it is reported as nitrogen in the form of nitrate (NO_3-N) because this is the usual form found in natural water.

Sensitive crops may be affected by nitrogen concentrations above 5 mg/l. Most other crops are relatively unaffected until nitrogen exceeds 30 mg/l. For example, sugarbeets, a sensitive crop, increase in size with excessive nitrogen fertilization but the sugar content and sugar purity are lower, thus the total quantity of recoverable sugar produced per hectare may actually be reduced. Grapes are also sensitive and may continue to grow late into the season at the expense of fruit production. Yields are often reduced and grapes may be late in maturing and have a lower sugar content. Experience in Libya indicated that almost no fruiting occurred in grapes when a water containing >50 mg/l of N was used continuously. Maturity of fruit such as apricot, citrus and avocado may also be delayed and the fruit may be poorer in quality, thus affecting the marketability and storage life. In many grain crops, excessive vegetative growth produces weak stalks that cannot support the grain weight, resulting in severe lodging and difficulties for machine harvesting. Lodging is especially serious in areas with high winds or periodic heavy rains. The new short-stature wheats are better adapted and are heavily fertilized without severe lodging. Ruminant animals are sensitive to nitrogen and heavy applications to pastures used for direct or indirect livestock feed may cause excessive quantities to accumulate in the forage. This may be hazardous to the animals' health.

The sensitivity of crops varies with the growth stage. High nitrogen levels may be beneficial during early growth stages but may cause yield losses during the later flowering and fruiting stages. High nitrogen water can be used as a fertilizer early in the season. However, as the nitrogen needs of the crop diminish later in the growing season, the nitrogen applied to the crop must be substantially reduced. Blending or changing supplies during the later more critical growth stages should be

helpful. Another option is to plant a less sensitive crop, such as maize, which can utilize the nitrogen from the irrigation water more effectively. For crops irrigated with water containing nitrogen, the rates of nitrogen fertilizer supplied to the crop can be reduced by an amount very nearly equal to that available from the water supply. Crop rotations can be planned to utilize residual nitrogen in the soil during the non-irrigation season. This may also be helpful in reducing the impact in succeeding years.

Less than 5 mg/l N has little effect, even on nitrogen sensitive crops, but may stimulate nuisance growth of algae and aquatic plants in streams, lakes, canals and drainage ditches. Very rapid growth of algae can occur when temperature, sunlight and other nutrients are optimum, and may result in plugged valves, pipelines and sprinklers requiring either mechanical controls such as screens and filters, or chemical control, with materials such as copper sulphate. Nitrogen in water also increases maintenance costs for clearing vegetation from canals and drainage channels.

Denitrification to remove NO_3-N from the water supply before use may be the only other alternative but is not used because of the high cost of equipment and energy. Since nitrogen is a valuable resource it should be utilized if possible.

5.2 ABNORMAL pH

pH is an indicator of the acidity or basicity of a water, but is seldom a problem by itself. The main use of pH in a water analysis is for detecting an abnormal water. The normal pH range for irrigation water is from 6.5 to 8.4. An abnormal value is a warning that the water needs further evaluation. Irrigation water with a pH outside the normal range may cause a nutritional imbalance or may contain a toxic ion.

Low salinity water (ECw < 0.2 dS/m) sometimes has a pH outside the normal range since it has a very low buffering capacity. This should not cause undue alarm other than to alert the user to a possible imbalance of ions and the need to establish the reason for the adverse pH through full laboratory analysis. Such water normally causes few problems for soils or crops but is very corrosive and may rapidly corrode pipelines, sprinklers and control equipment.

Any change in the soil pH caused by the water will take place slowly since the soil is strongly buffered and resists change. An adverse pH may need to be corrected, if possible, by the introduction of an amendment into the water, but this will only be practical in a few instances. It may be easier to correct the soil pH problem that may develop rather than try to treat the water. Lime is commonly applied to the soil to correct a low pH and sulphur or other acid material may be used to correct a high pH. Gypsum has little or no effect in controlling an acid soil problem apart from supplying a nutritional source of calcium, but it is effective in reducing a high soil pH (pH greater than 8.5) caused by high exchangeable sodium.

The greatest direct hazard of an abnormal pH in water is the impact on irrigation equipment. Equipment will need to be chosen carefully for unusual water (see Section 5.8).

5.3 SCALE DEPOSITS

Irrigation water containing a high proportion of slightly soluble salts such as calcium, bicarbonate and sulphate presents a continual problem of white scale formation on leaves or fruit when sprinklers are used. Although there is no toxicity involved, the deposits often build up on the leaves and fruit and are of special concern when flowers, vegetables or fruits are grown for the fresh market. The deposit reduces the marketability of fruit and foliage and, in the case of fruit like apples and pears, requires an expensive treatment (acid wash) before marketing. (Small drip emitters are also subject to deposits accumulating near small openings, resulting in clogging. This clogging problem is covered in Section 5.7.)

The principal problem is caused by calcium in combination with bicarbonate and occasionally with sulphate (gypsum). Deposits form even at very low concentrations if sprinklers are used during

periods of very low humidity (less than 30 percent), resulting in a high rate of evaporation. Between rotations or cycles of certain sprinkler types, the droplets left on the leaves partially evaporate to concentrate the salts. If the concentration is great enough, the less soluble salts such as lime ($CaCO_3$) and gypsum ($CaSO_4$) will precipitate and once precipitated will not readily re-dissolve during subsequent wettings as the sprinkler rotates. Deposits then begin to build up. These may become a serious problem with certain water when newer types of sprinkler systems are used that apply light, frequent applications or have high pressure which presents a hazard from drift to adjacent areas.

Management options to prevent or correct a deposit problem will depend upon the concentration and the irrigation method. One technique is to add an acid material to the water supply to reduce the bicarbonate, which should in turn reduce the lime precipitate. This has been used for special ornamental and foliage crops grown in the greenhouse. One recommendation has been to add sulphuric acid to 90 percent of the HCO_3 equivalent (personal communication, Rhoades 1976). The acidifying effects of sulphuric acid are immediate, but the acid is difficult and hazardous to handle and application is normally made on a contract basis by experienced people. With the high level of skill needed for application, such an operation will most likely be costly and restricted to high income crops. As with any acid material, the low pH may cause damage to pipelines, sprinklers and other equipment, and careful choice of resistant materials will be necessary or pH must be carefully controlled. A pH not less than pH 6.5 seems to be safe for sprinklers.

An alternative approach might be to change the design and operation of the sprinkler system. This will probably not solve the problem but may minimize it so as to make the product more marketable. The same steps taken to reduce toxicity effects (leaf absorption) due to sprinkler irrigation will also reduce deposits on leaves and fruit (see Section 4.3). The most useful measures are:

- irrigate at night
- increase the speed of sprinkler rotation or use spray heads
- decrease the frequency of irrigation.

These management steps may reduce the problem but they must be cost efficient. Under some circumstances, it may be more economical to change to an alternative form of irrigation which keeps the water off fruit and foliage.

5.4 MAGNESIUM PROBLEMS

Soils containing high levels of exchangeable magnesium are often thought to be troubled with soil infiltration problems. The role of magnesium in causing or partly causing these problems is not well documented but researchers from several irrigated areas have studied the problem. At present there is reasonably good agreement that magnesium acts on soils in a way which is more like calcium than sodium, and that it is preferentially adsorbed by the soil to a much greater degree than sodium but to a slightly less degree than calcium.

In a magnesium dominated water (ratio of Ca/Mg < 1) or a magnesium soil (soil-water ratio of Ca/Mg < 1), the potential effect of sodium may be slightly increased. In other words, a given SAR value will show slightly more damage if the Ca/Mg ratio is less than 1. The lower the ratio, the more damaging is the SAR. Research findings show that at a given SAR of the applied water, a higher soil ESP than normal will result when using a water with a Ca/Mg ratio less than 1 (Rahman and Rowell 1979).

One concern, however, is that productivity is sometimes reported to be low on high magnesium soils or on soils being irrigated with high magnesium water even though infiltration problems may not be evident. The effect may be due to a magnesium-induced calcium deficiency caused by high levels of exchangeable magnesium in the soil. Some research evidence shows that yields of crops such as barley, wheat, maize and sugarbeets are reduced when the Ca/Mg ratio in soil-water is less than

one. The function of calcium in plants is not totally understood, but calcium appears to reduce possible toxicities due to other ions (Na, Mg) in the root environment. If the Ca/Mg ratio is near or less than 1, the uptake and translocation of Ca from soil-water to the above-ground parts of the growing crop is diminished due to antagonistic effects of high magnesium or competition for absorption sites to such an extent that less calcium is absorbed. A calcium deficiency may then be experienced at a higher calcium concentration in the applied water or in soil-water than would occur if the Ca/Mg ratio were higher. Although not definitely confirmed, it can be anticipated that irrigation water with a similar ratio (Ca/Mg < 1) will produce a similar effect if a readily available source of calcium is not present in the soil.

Other limited research indicates that the ratio of calcium to total cations in the soil-water may also be critical. A calcium to total cation ratio of 0.10 – 0.15 or greater has been mentioned as needed for optimum root growth of barley and cotton.

There are insufficient data to make either the Ca/Mg ratio or the calcium to total cation ratio an evaluation factor when judging the suitability of a water for irrigation, but if an irrigation water is being used that has a Ca/Mg ratio less than one, or a calcium to total cation ratio less than 0.15, a further evaluation is needed. Although no conclusive recommendations can be made, such water may pose a potential problem related to plant nutrition and an evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment.

Additional references include: Paliwal and Gandhi (1976); Koenigs and Brinkman (1964); Howard and Adams (1965); Simpson **et al**. (1979); Carter and Webster (1979); Ulrich and Mostafa (1976); Fong and Ulrich (1970).

5.5 TRACE ELEMENTS AND THEIR TOXICITY

5.5.1 Natural Occurrence in Water

Trace elements occur in almost all water supplies but at very low concentrations, usually less than a few mg/l with most less than 100 micrograms per litre (µg/1). They are not often included in a routine analysis. Surface water normally contains lower concentrations than groundwater, but this is variable and no general guidelines can be given. As a rule of thumb, irrigation water supplies do not need to be checked for trace elements unless there is some reason to suspect toxicity. In almost all cases where trace elements are at high levels, they are the result of man's activities, particularly wastewater disposal. Any project using wastewater should check for trace elements.

5.5.2 Toxicities

Not all trace elements are toxic and in small quantities many are essential for plant growth (Fe, Mn, Mo, Zn). However, excessive quantities will cause undesirable accumulations in plant tissue and growth reductions. There have been few field experiments from which toxic limits could be established, especially for irrigation water. However, research dealing with disposal of wastewater has gained sufficient experience to prove useful in defining limitations. It is now recognized that most trace elements are readily fixed and accumulate in soils, and because this process is largely irreversible, repeated applications of amounts in excess of plant needs eventually contaminate a soil and may either render it non-productive or the product unusable. Recent surveys of wastewater use have shown that more than 85 percent of the applied trace element accumulates in the soil and most accumulates in the surface few centimetres (Figure 23). Although plants do take up the trace elements, the uptake is normally so small that this alone cannot be expected to reduce appreciably the trace element in the soil in any reasonable period of time.

Fig. 23
Heavy
metal

content of the soil profile after 80 years of irrigation with wastewater (Evans, Mitchell and Salau 1979)

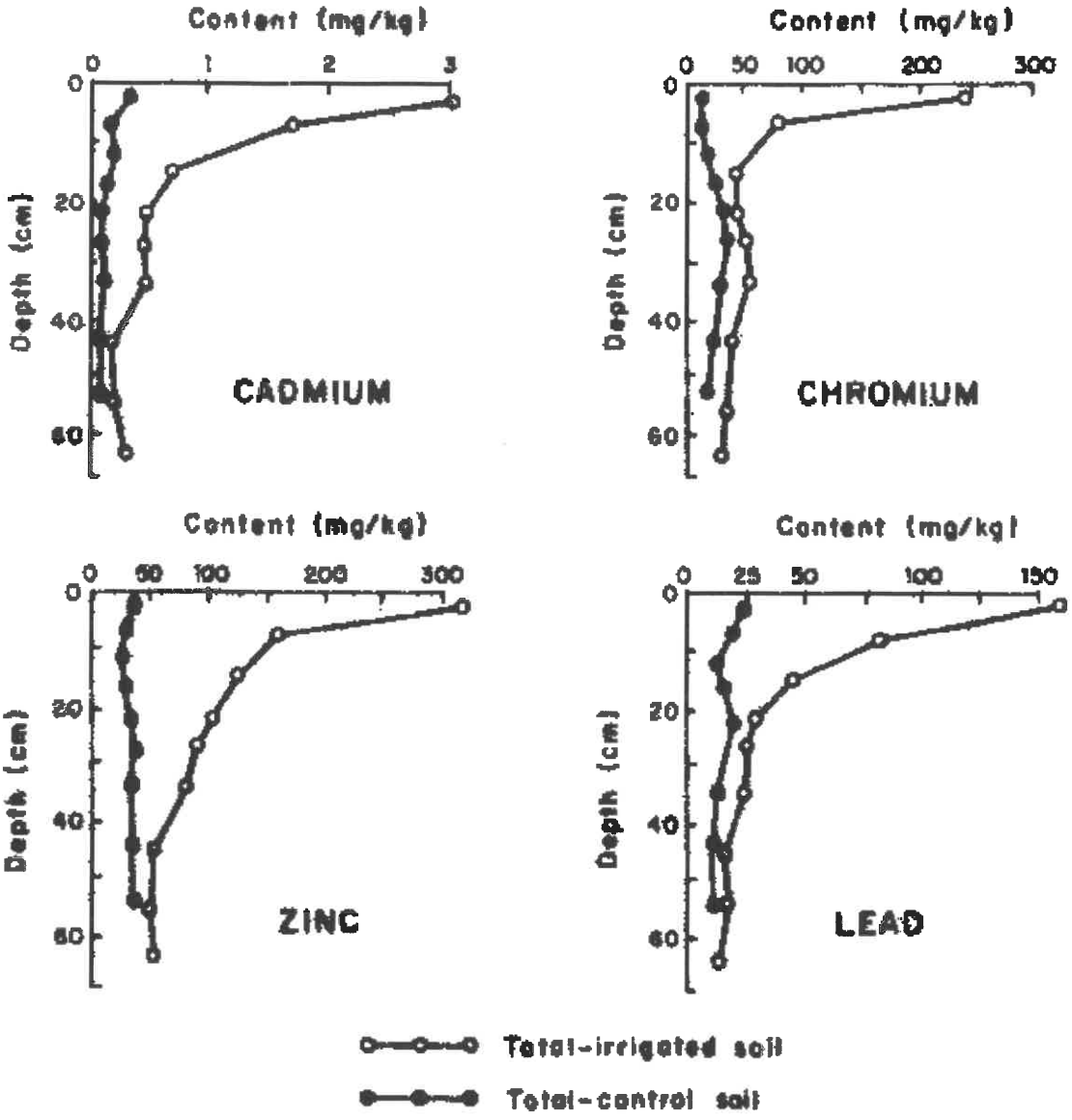

Table 21 RECOMMENDED MAXIMUM CONCENTRATIONS OF TRACE ELEMENTS IN IRRIGATION WATER[1]

Element	Recommended Maximum Concentration[2] (mg/l)	Remarks
Al(aluminium)	5.0	Can cause non-productivity in acid soils (pH < 5.5), but more alkaline soils at pH > 7.0 will precipitate the ion and eliminate any toxicity.
As (arsenic)	0.10	Toxicity to plants varies widely, ranging from 12 mg/l for Sudan grass to less than 0.05 mg/l for rice.
Be (beryllium)	0.10	Toxicity to plants varies widely, ranging from 5 mg/l for kale to 0.5 mg/l for bush beans.
Cd (cadmium)	0.01	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans.

Co (cobalt)	0.05	Toxic to tomato plants at 0.1 mg/l in nutrient solution. Tends to be inactivated by neutral and alkaline soils.
Cr (chromium)	0.10	Not generally recognized as an essential growth element. Conservative limits recommended due to lack of knowledge on its toxicity to plants.
Cu (copper)	0.20	Toxic to a number of plants at 0.1 to 1.0 mg/l in nutrient solutions.
F (fluoride)	1.0	Inactivated by neutral and alkaline soils.
Fe (iron)	5.0	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum. Overhead sprinkling may result in unsightly deposits on plants, equipment and buildings.
Li (lithium)	2.5	Tolerated by most crops up to 5 mg/l; mobile in soil. Toxic to citrus at low concentrations (<0.075 mg/l). Acts similarly to boron.
Mn (manganese)	0.20	Toxic to a number of crops at a few-tenths to a few mg/l, but usually only in acid soils.
Mo (molybdenum)	0.01	Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum.
Ni (nickel)	0.20	Toxic to a number of plants at 0.5 mg/l to 1.0 mg/l; reduced toxicity at neutral or alkaline pH.
Pd (lead)	5.0	Can inhibit plant cell growth at very high concentrations.
Se (selenium)	0.02	Toxic to plants at concentrations as low as 0.025 mg/l and toxic to livestock if forage is grown in soils with relatively high levels of added selenium. An essential element to animals but in very low concentrations.
Sn (tin)		
Ti (titanium)	----	Effectively excluded by plants; specific tolerance unknown.
W (tungsten)		
V (vanadium)	0.10	Toxic to many plants at relatively low concentrations.
Zn (zinc)	2.0	Toxic to many plants at widely varying concentrations; reduced toxicity at pH > 6.0 and in fine textured or organic soils.

[1] Adapted from National Academy of Sciences (1972) and Pratt (1972).

[2] The maximum concentration is based on a water application rate which is consistent with goodirrigation practices (10 000 m^3 per hectare per year). If the water application rate greatly exceeds this, the maximum concentrations should be adjusted downward accordingly. No adjustment should be made for application rates less than 10 000 m^3 per hectare per year. The values given are for water used on a continuous basis at one site.

5.5.3 Evaluation Criteria

With the high retention rate in the soil and the low use by plants, ideally the maximum application rate should not exceed that which will allow normal crop growth and still not exceed any allowable concentration in the produce coming from the field. Suggested maximum concentrations of trace elements in irrigation water are shown in Table 21. These concentrations are set because of concern for long-term build-up of trace elements in the soil and for protection of the agricultural soil resource from irreversible damage. Under normal irrigation practices, these suggested levels should prevent a build-up that might limit future crop production or utilization of the product. Whether wastewater is used as all or only a part of the supply will not modify these guidelines as they are based on protection of the soil resource to assure its present and future production capability.

The guidelines reflect the current information available but as they are supported by only limited, long-term field experience, they are necessarily conservative, which means that, if the suggested limit is exceeded, a phytotoxicity still may not occur. The suggested limits in Table 21 are to ensure that the site can be used for all potential crops in the future. It is recommended that the values be

considered as the maximum long-term average concentration based upon normal irrigation application rates. When more reliable data become available, the levels may be adjusted. If water above or close to the levels given in Table 21 is considered for use, an up-to-date review of more recent information is suggested to prevent possible future problems.

5.6 NUTRITION AND WATER QUALITY

Water quality has been discussed in this paper based upon four different effects on crops or soils: salinity, reduced water infiltration, toxicity, or effects related to a group of miscellaneous water constituents. These effects sometimes cause nutritional imbalances or interactions which result in nutritional imbalances.

5.6.1 Nutrition and Salinity

Excessive salinity stunts the crop by reducing the availability of soil-water, slowing crop growth and restricting root development. With higher salinity water, sodium and chloride toxicity are also likely to be evident. As long as the crop is well supplied with fertilizer elements, application of extra nutrients to combat the salinity effects will not improve yield. However, if nutrients such as nitrogen are in short supply, raising the nutrient level will usually improve yield. Saline areas in the field are normally dark green to blue-green, indicating that they are well supplied with nitrogen. If yellow, additional nitrogen should improve yield.

Most fertilizers, however, are water soluble salts and placement and rates of use must take into consideration their potential salinity impact. (See Table 9 for relative salinity of representative fertilizers.)

Plant tissue analysis for an annual crop is useful to confirm the presence or absence of a calcium deficiency. For example, with potato, petioles or leaf material from the most recent fully-formed leaves are normally used. Calcium (dry weight basis) below 0.15 percent is probably indicative of a calcium deficiency, while values in the range of 0.15 to 0.20 percent may be suspect. Table 11 may also be used to predict a probable calcium deficiency through the Cax value. Cax values less than about 1 me/l are often associated with deficiency.

The ratio of Ca/Mg or calcium to total cations (Ca/TC) in the soil-water may also be used to predict a potential calcium deficiency. There are reports that Ca/Mg ratios less than 1 or Ca/TC less than 0.15 are sometimes associated with calcium deficiencies (Ca, Mg and TC in me/l) (see Section 5.4).

5.6.2 Water Infiltration Problems and Nutrition

A severe reduction in water infiltration rate due to water quality is usually related to either very low water salinity or to a high sodium adsorption ratio (SAR). In either case, the calcium content of the water may be at a relatively low concentration. If the calcium in the soil-water taken up by the crop is less than 2 me/l, there is a strong probability that the crop yield will be reduced due to a calcium deficiency (Rhoades 1982). A potential evaluation technique is to use the Cax values in Table 11 to prevent a possible calcium deficiency. Irrigation water for which a predicted equilibrium soil-water calcium (Cax) is less than 0.7 me/l at LF = 0.15 or is less than 1.0 me/l at LF = 0.30 may result in a calcium deficiency. In such cases, calcium fertilization using granular gypsum or a calcium source included in the fertilizer mix to supply calcium may restore production potential.

Iron chlorosis in susceptible crops (maize, sorghum, Sudan grass, and a few others) is sometimes caused by water with a relatively high sodium adsorption ratio (SAR > 6) and can often be corrected by repeated sprays of ferrous iron or iron chelate, or by using soil sulphur or gypsum to maintain soil pH less than 8.5 or, as with Sudan grass, withholding of water (delayed irrigation) for several days may improve aeration and correct the chlorosis.

Zinc deficiency of paddy rice, too, has been associated with sodic soils and a high soil pH (pH > 8.5). In other cases, zinc deficiency has been attributed to a high bicarbonate level in the applied water (HCO_3 > 2.0 me/l) (see Section 5.6.3).

If soils become waterlogged and temporarily flooded due to a reduced water infiltration rate for even short periods of a few days, and if they lack good aeration, much of the nitrate-nitrogen present may be quickly denitrified and lost from the soil to the atmosphere as N_2 gas. In such cases, the crop may soon show yellowed areas indicating depleted nitrogen and will benefit from added fertilizer nitrogen.

5.6.3 Nutrition and Toxicity

Sodium, chloride or boron from the irrigation water, taken up by the crop with the soil-water, gradually accumulate in the leaves. If these toxic ions accumulate to excessive concentrations, they cause chlorosis, bronzing and leaf burn (necrosis) primarily at the leaf top, leaf edges and, in more severe cases, symptoms may extend between the veins from the leaf edges toward the mid-leaf area.

Leaf necrosis caused by boron can sometimes be severe enough to reduce markedly the total leaf surface available for photosynthesis. For tree crops such as citrus, if boron accumulation threatens to reduce total leaf area appreciably, extra nitrogen fertilization has been applied to stimulate additional vegetative growth to counteract this effect.

In the case of sodium and chloride toxicities, reliance is placed upon selection of cultivars and rootstocks more tolerant to sodium or chloride. Additional fertilization does not appear to be effective.

Bicarbonate, although not ordinarily thought to be a toxic ion, is reported to cause zinc deficiency in rice. Bicarbonate in excess of 2 me/l in the water used for flooding and growing paddy rice is reported to cause severe zinc deficiency (Mikkelson 1983). This can be remedied by adding zinc to soil before flooding or at the time of earliest appearance of the chlorosis. Actual zinc of 8 to 10 kg/ha from zinc oxide or zinc sulphate is surface applied to remain in the upper 5 to 10 cm of soil.

5.6.4 Miscellaneous

Nitrogen in the applied irrigation water is generally beneficial to most crops but may cause problems for some. Nitrogen in the irrigation water is readily available and if present should be considered as an important part of the fertilizer programme. For most crops, this nitrogen is equivalent to fertilizer nitrogen and should be included in the total nitrogen planned for application. For a few crops, however, the added nitrogen from the water may be too much and result in excessive and vigorous growth, delayed or uneven maturity, and reduced quality. These sensitive crops include apricots, grapes, sugarbeets and cotton, but there are probably others.

In such cases, the stimulating nitrogen can be reduced by applying less water: apply the minimum depth required to supply the crop water demand. If water applied nitrogen is still excessive, irrigate to cause a moderate but increasing water stress as the crop approaches maturity.

Soils high in magnesium or high magnesium water may cause a calcium-induced nutritional deficiency. This is discussed in Section 5.4.

5.7 CLOGGING PROBLEMS IN LOCALIZED (DRIP) IRRIGATION SYSTEMS

A localized (drip) irrigation system is designed to deliver a very low rate of water application to the plant. Understandably, the water must pass through very small openings or emitters which invite clogging problems. A completely blocked opening is easily noticed, but a partially clogged one is

very difficult to detect. Detection of partial clogging might involve measuring the delivery of each opening which would be an endless task. Plugging results in decreased uniformity of application and higher operational costs due to increased labour requirements to detect and correct it. Plugging can be prevented if the system is properly planned and designed. Installation of proper equipment to prevent clogging at the beginning is usually less expensive than to try to correct the problem afterwards. Recognizing potential problems beforehand should, therefore, carry a high priority. References include: Nakayama (1982); Vermeiren and Jobling (1980); Bucks **et al.** (1979); Ford and Tucker (1974).

The potential for clogging problems is often related to water quality. The principal physical, chemical and biological contributors to clogging problems are summarized in Table 22. Often these factors are interrelated and the severity can be worsened by a combination; for example, bacterial slime growths inside distribution and emitter lines may cause further plugging when flow is reduced and suspended particles stick to the slime growths.

Table 22 PHYSICAL, CHEMICAL AND BIOLOGICAL CONTRIBUTORS TO CLOGGING OF LOCALIZED (DRIP) IRRIGATION SYSTEMS AS RELATED TO IRRIGATION WATER QUALITY[1]

PHYSICAL (Suspended Solids)	CHEMICAL (Precipitation)	BIOLOGICAL (Bacteria and algae)
1. Sand	1. Calcium or magnesium carbonate	1. Filaments
2. Silt	2. Calcium sulphate	2. Slimes
3. Clay	3. Heavy metal hydroxides, oxides, carbonates, silicates and sulphides	3. Microbial depositions:
		(a) Iron
		(b) Sulphur
		(c) Manganese
4. Organic matter	4. Fertilizers	4.Bacteria
	(a) Phosphate	
	(b) Aqueous ammonia	
	(c) Iron, zinc, copper, manganese	5.Small aquatic organisms
		(a) Snail eggs
		(b) Larva

[1] Adapted from Bucks et al. (1979).

It is recommended that a complete water analysis be conducted before a system is designed in order to allow for treatment to improve water quality before it reaches the small openings. It should be kept in mind that there can be large fluctuations in water quality during a single irrigation cycle, especially if surface water is used. Therefore, a series of analyses should be taken. This series will disclose water quality variations and also indicate how particular pieces of equipment will perform during certain times of the year.

The analysis needed will vary with each situation but localized irrigation systems are expensive and the cost of analysis is so small compared to the total investment that all the standard tests in Table 23 should be completed.

Table 23 STANDARD WATER QUALITY TESTS NEEDED FOR DESIGN AND OPERATION OF LOCALIZED (DRIP) IRRIGATION SYSTEMS

1. Major Inorganic Salts (see Table 2)
2. Hardness[1]
3. Suspended Solids
8. Micro-organisms
9. Iron
10. Dissolved Oxygen

4. Total Dissolved Solids (TDS)[1]
5. BOD (Biological Oxygen Demand)
6. COD (Chemical Oxygen Demand)
7. Organics and Organic Matter
11. Hydrogen Sulphide
12. Iron Bacteria
13. Sulphate Reducing Bacteria

[1] A calculated value from analyses included in Table 2.

For surface water, particular attention should be given to tests 1–4 as the major problems usually occur from suspended material or chemical deposits. It is recommended, however, that tests 5–8 be included as a check, especially if wastewater is suspected in the water supply. When groundwater is used, tests 1–4 and 9–13 are considered to be a minimum, especially if ECw > 1.0 dS/m.

There is not enough experience with localized (drip) irrigation systems to predict with precision if or when clogging problems will occur with a given water. Experience gained so far, however, does allow us to prepare a relative scale for situations when clogging problems may occur due to water quality. Table 24 presents a first approximation of potential problems but should not be used to provide firm criteria; rather, situations which indicate slight to severe potential for restrictions may need a testing programme to determine the economics of solutions that must be considered. A rating of no restriction may also develop a problem but the costs of solving the problem are usually within the capability of irrigated agriculture.

Table 24 INFLUENCE OF WATER QUALITY ON THE POTENTIAL FOR CLOGGING PROBLEMS IN LOCALIZED (DRIP) IRRIGATION SYSTEMS[1]

Potential Problem	Units	Degree of Restriction on Use		
		None	Slight to Moderate	Severe
Physical				
Suspended Solids	mg/l	< 50	50 – 100	> 100
Chemical				
pH		< 7.0	7.0 – 8.0	> 8.0
Dissolved Solids	mg/l	< 500	500 – 2000	> 2000
Manganese[2]	mg/l	< 0.1	0.1 – 1.5	> 1.5
Iron[3]	mg/l	< 0.1	0.1 – 1.5	> 1.5
Hydrogen Sulphide	mg/l	< 0.5	0.5 – 2.0	> 2.0
Biological				
Bacterial populations	maximum number/ml	<10 000	10 000 – 50 000	>50 000

[1] Adapted from Nakayama (1982).

[2] While restrictions in use of localized (drip) irrigation systems may not occur at these manganese concentrations, plant toxicities may occur at lower concentrations(see Table 21).

[3] Iron concentrations > 5.0 mg/l may cause nutritional imbalances in certain crops(see Table 21).

The chief cause of clogging is solid particles in suspension, but this is also the easiest problem to solve. Suspended particles are most frequent in surface water but can also occur in groundwater from sand and silt pumped from wells. Suspended particles consist of soil particles of different sizes, lime carbonates, solid material washed into canals, algae, and eroded material from reservoirs. Particles heavier than water can be filtered or settled out. The oldest and cheapest method is sedimentation but this may not provide the consistent quality needed. Filtration is more reliable and consists of screening or passage through a suitable medium, normally graded sand. Screening alone is not adequate to prevent clogging in all cases, as small particles may still get through the screens. Various screening materials and filters are available as well as new emitter designs, some of which are self-cleaning and these greatly reduce the plugging hazard.

Another cause of clogging is chemical precipitation of materials such as lime ($CaCO_3$) and phosphates ($Ca_3(PO_4)_2$). Normally this is gradual and difficult to locate. High temperatures or high pH are usually part of the precipitation problem. Precipitation can result from an excess of calcium or magnesium carbonates and sulphates, or from iron which is in the ferrous form but when in contact with oxygen is oxidized to the insoluble ferric form (reddish-brown precipitate).

The tendency of a water to cause calcium precipitation can be predicted although there is no proven practical method to evaluate how serious the problem will be since it depends upon many factors. A first approximation of the calcium precipitation can be made using the saturation index of Langelier which simply says that upon reaching the calcium saturation point in the presence of bicarbonate, lime ($CaCO_3$) will precipitate from the solution. The saturation index is defined as the actual pH of the water (pHa) minus the theoretical pH (pHc) that the water could have if in equilibrium with $CaCO_3$.

$$\text{Saturation Index} = pHa - pHc \qquad (18)$$

Positive values of the index (pHa > pHc) indicate a tendency for $CaCO_3$ to precipitate from the water whereas negative values indicate that the water will dissolve $CaCO_3$. The value of pHa is obtained from laboratory data, while pHc is estimated using the procedures described in Table 25. All water having positive values should be considered as potential problem water for use through drip systems and the need for preventative measures should be considered in design. For example, an irrigation water with a measured pH of 7.7, Ca = 3.65 me/l, HCO_3 = 3.80 me/l and total salts of 8.23 me/l (Ca + Mg + Na) will have a theoretical pH of 7.4, giving a saturation index of +0.3, which indicates a possibility of carbonate (lime) precipitation. This may or may not result in a plugging problem but if the pH is adjusted to 7.0 by acid addition, the saturation index becomes -0.4 and carbonate precipitation should not occur. From Table 24, a problem is much more likely at a measured pH greater than pH = 8.0; this is the pH of water close to equilibrium with finely ground limestone ($CaCO_3$).

Iron is more difficult to evaluate for its clogging potential as it is frequently a contributor to other problems, especially those of iron bacterial slime. The limitation given in Table 21 of 5 mg/l should be considered a maximum for drip irrigation systems but, in practical terms, a value above 2.0 may be near maximum since filtration costs become excessive above this limit. A concentration of 0.5 mg/l should be considered a potential problem if tannin-like compounds (often in acid waters) or total sulphides exceed 2 mg/l. The combination of the two normally produces undesirable slime growths.

To prevent iron precipitation in lines or at the emitters iron should be precipitated and filtered out before it enters the irrigation system. In order to filter out the iron, it must first be oxidized to the insoluble form, usually by chlorination to a residual of 1 mg/l chlorine. An alternative method is aeration in an open pond or by injection of air into the water supply by mechanical means. This causes oxidized iron to precipitate. Then it can be filtered and removed before the water enters the irrigation line. Both are expensive and difficult processes and the practicality of treatment plus filtering should be evaluated.

The most effective method of preventing problems caused by precipitation of calcium carbonate is to control the pH or to clean the system periodically with an acid in order to prevent deposits building up to levels where clogging might occur. A common practice among those with problems is to inject hydrochloric (muriatic) or sulphuric acid into the system periodically. The system may need to be flushed as often as once a week.

Table 25 PROCEDURE FOR CALCULATION OF pHc[1,2]

$pHc = (pK_2 - pKc) + pCa + p(Alk)$	
pK_2 - pKc is obtained from the concentration of Ca + Mg + Na in me/l pCa is obtained from the Ca in me/l p(Alk) is obtained from the concentration of $CO_3 + HCO_3$ in me/l	Obtained from the water analysis

Concentration (me/l)	pK_2 - pKc	pCa	p(Alk)
0.05	2.0	4.6	4.3
0.10	2.0	4.3	4.0
0.15	2.0	4.1	3.8
0.20	2.0	4.0	3.7
0.25	2.0	3.9	3.6
0.30	2.0	3.8	3.5
0.40	2.0	3.7	3.4
0.50	2.1	3.6	3.3
0.75	2.1	3.4	3.1
1.00	2.1	3.3	3.0
1.25	2.1	3.2	2.9
1.50	2.1	3.1	2.8
2.00	2.2	3.0	2.7
2.50	2.2	2.9	2.6
3.00	2.2	2.8	2.5
4.00	2.2	2.7	2.4
5.00	2.2	2.6	2.3
6.00	2.2	2.5	2.2
8.00	2.3	2.4	2.1
10.00	2.3	2.3	2.0
12.50	2.3	2.2	1.9
15.00	2.3	2.1	1.8
20.00	2.4	2.0	1.7
30.00	2.4	1.8	1.5
50.00	2.5	1.6	1.3
80.00	2.5	1.4	1.1

[1] Procedure from Nakayama (1982).

[2] pHc is a theoretical, calculated pH of the irrigation water.

The acid can be added to the system on a continuous basis if the problem is severe enough but this is expensive and difficult and the acid is dangerous to handle. It is recommended that acid be added at a rate to maintain pH close to but not lower than pH 6.5. Sulphur burners have also been used to acidify the supply water for drip irrigation. The SO_2 formed is put into the irrigation water by means of water spray scrubbers that form H_2SO_3 and H_2SO_4 acidified solutions.

If fertilizers are injected into the irrigation water, possible precipitation due to water chemistry must be considered. For example, if calcium (Ca) concentration is greater than 6 me/l, most phosphorus fertilizers will cause clogging of emitters. Clogging is more severe if bicarbonates are high (>5 me/l). Anhydrous or liquid ammonia should not be applied through these systems as the ammonia can increase pH of the water to values above 11 and cause rapid precipitation of $CaCO_3$ which clogs the entire system.

Many cases of clogging have occurred from biological growths inside the irrigation lines and openings. These are caused by small quantities of micro-organisms such as algae, slimes, fungi, bacteria, snails, and miscellaneous larvae. These problems are difficult to evaluate and prevent since they are affected by a number of factors. Such problems occur when the water contains organics and iron or hydrogen sulphide. One of the most severe forms of clogging is caused by a

white, gelatinous sulphur slime associated with sulphur bacteria. Another common one is the brown slime mass caused by filamentous iron bacteria. These grow rapidly in water containing as low as 0.4 me/l iron and are especially troublesome in water containing soluble dark, tannin-like organics which act as a readily available food source for the bacteria. Algae and other growths can cause problems especially if their growth rates are enhanced by excess nutrient levels (nitrogen or phosphorous). The use of wastewater in localized (drip) irrigation systems would be especially troublesome since effluents normally contain nutrients, dissolved organics, and micro-organisms, all of which may increase the potential for clogging problems.

Chemical treatment (chlorine) is one of the most effective methods for controlling biological growths but is costly and requires close and careful management to use safely. Chlorine kills the organism, oxidizes the organic matter and may require filtering or flushing of the system to clear the organic matter. Continuous chlorine injection is an excellent method but may be too expensive for most agricultural use. Its efficiency is related to the pH of the water, with more chlorine required at higher pH. Table 26 gives examples of typical chlorine dosages used in localized (drip) irrigation systems to inhibit microbial growth, slime and bacterial development.

Table 26 CHLORINE DOSAGES FOR CONTROL OF BIOLOGICAL GROWTHS[1]

Problem	Dosage
Algae	0.5–1.0 mg/l continuous or 20 mg/l for 20 minutes
Hydrogen Sulphide	3.5–9.0 times the hydrogen sulphide content (mg/l)
Iron Bacteria	1.0 mg/l but varies with bacterial count
Slimes	0.5 mg/l continuous

[1] Data from Vermeiren and Jobling (1980).

5.8 CORROSION AND ENCRUSTATION

5.8.1 Metal Corrosion

Most corrosion and encrustation problems are associated with groundwater. Groundwater varies significantly in composition from one area to another but most types are at least mildly corrosive to iron and some will severely attack it and even affect more resistant metals. Corrosion is basically an electrolytic process which attacks and dissolves away a metal surface. The rate at which corrosion proceeds depends upon a variety of chemical equilibrium reactions as well as upon certain physical factors such as velocity, temperature and pressure. Most corrosion problems are associated with low salinity water; most encrustation problems are associated with higher salinity groundwater.

Other types of groundwater may cause unusual amounts of organic and inorganic materials to be deposited on equipment and in wells. These deposits may restrict water passage in well screens, pipelines, and outlets. Although an endless variety of dissolved and suspended solids can cause such effects, the more common ones are sand, silt, carbonate deposition, iron, and biological growths.

Corrosion and encrustation processes are complex and interactive. For this reason, no single test or index is an infallible indicator of the potential life of equipment. Nevertheless, certain accelerated performance tests and chemical indicators have proved to be of considerable value in planning equipment needs and evaluating performance. Considering the high cost of well construction and irrigation equipment, it is desirable to apply all known indicator tests and to use the most conservative (safest) in planning for fullscale development. Because of the varying nature of the tests, it is suggested that reputable reference guides be used to make the appraisal. One of the latest guides is Corrosion and Encrustation in Water Wells: A Field Guide for Assessment, Prediction and Control (Clarke 1980). Although this deals with water wells, the predictive tools could also be applicable to irrigation equipment.

5.8.2 Concrete Corrosion

Groundwater and certain surface water supplies can be corrosive to concrete. This corrosion may affect the life of an irrigation canal lining but the most frequent corrosion occurs when groundwater is pumped through a closed concrete pipeline.

There are three general types of corrosion that might result in deterioration in concrete canals and pipelines when they are exposed to a corrosive water:

TYPE I: Leaching corrosion is when lime in concrete is dissolved by low salinity soft water (low carbonate hardness) or by water that contains free carbon dioxide (carbonic acid). This type of corrosion does not do excessive damage to good concrete but can be pronounced in poor quality, porous concrete. The rate of this type of corrosion in dense concrete is very slow to nonexistent but can be relatively rapid in jointing materials.

For water containing carbonic acid ($H_2 CO_3$), the pH may vary from 4.5 to 7.9, therefore, pH should not be a sole indicator. A characteristic of low salinity water is that even though the pH may vary between 7.0 and 7.9, the water may still attack concrete. This is because it may be 'lime dissolving' instead of lime depositing. Therefore, it is advisable to check the Langelier Saturation Index of the water (see Section 5.7 and Equation 18). If the saturation index is negative, then some attack on concrete is likely but the rate of attack will be very slow. The Cax values in Table 11 may also indicate a corrosion potential since concrete would be a good source of lime ($CaCO_3$).

TYPE II: Ion exchange corrosion occurs as a result of base exchange reactions between the readily soluble compounds in the hardened cement and the alkaline cations (Ca, Mg, K, NH_4) in the water. The exchange products are then leached or remain in place in the concrete as non-binding components. Magnesium and salts are commonly involved.

TYPE III: Corrosion by expansion occurs from a chemical reaction that results in the formation of compounds which occupy a greater volume than the original cement compounds, thus causing internal stress which ultimately destroys the concrete by swelling. Sulphates are a known cause of this type of corrosion. The sulphates tend to combine with some of the calcium and aluminium compounds in the hardened cement and form calcium aluminate-sulphate or gypsum, which causes the concrete to swell. It should be noted that some sulphates are potentially more aggressive than others; these are magnesium and ammonium sulphates. The increased aggression by $MgSO_4$ and NH_4SO_4 is due to the fact that they decompose the hydrated calcium silicates (Type II corrosion) in addition to reacting with the aluminium and calcium hydroxide in the concrete. The action of ammonium sulphate may be enhanced in the presence of nitrate. Both may be present in water supplies especially if they are receiving industrial wastes or runoff from agricultural land.

As with metals, corrosion processes of concrete are complex, therefore, no single test or index is an infallible indicator. Guidelines have been suggested to estimate the potential of a water to be aggressive against concrete (Table 27). These are relative degrees of aggressivity of water of predominantly natural origin and do not take into account resistance of the concrete to corrosion. The developer of Table 27 suggests that even if only one of the values points to a potential, a further evaluation should be made.

Table 27 LIMIT VALUES FOR EVALUATING THE AGGRESSIVITY OF WATER AND SOIL TO CONCRETE[1]

Test	Intensity of attack			
	None to slight	Mild	Strong	Very Strong
Water				
pH	>6.5	6.5 – 5.5	5.5 – 4.5	<4.5
Lime-dissolving carbonic acid (CO_2), mg/l	<15	15–30	30–60	>60
Ammonium (NH_4), mg/l	<15	15–30	30–60	>60

Magnesium (Mg), mg/l	<100	100–300	300–1500	>1500
Sulphate in water (SO_4), mg/l	<200	200–600	600–3000	>3000
Soil				
Sulphate in soil (air-dry) (SO_4), mg/kg	<2000	2000–5000	>5000	

[1] Data taken from Biczok (1972).

Further references include: Biczok (1972); United States Bureau of Reclamation (1975); Taylor (1977); and Perkins (1981).

5.9 VECTOR PROBLEMS ASSOCIATED WITH WATER QUALITY

In most countries where there is a risk to health from vectorborne diseases such as malaria, lymphatic filariasis, encephalitis, onchocerciasis, schistosomiasis, there is an awareness of the possibility that water development projects may have an impact on vector populations and human health. This is particularly true of irrigation schemes, which tend to increase opportunities for human/water/vector contact in addition to their creation of habitats well suited to vector production. Even in the absence of an associated disease, a similar problem may arise in relation to nuisance species of insects which cause personal discomfort and can be extremely disruptive of community life, work and leisure activities.

The existence of an aquatic environment is usually the primary cause of these problems, and there is ample-literature on vector control through chemical, biological and environmental management methods. However, there is less information on the relationships between water quality and vector production although quality aspects may often intensify a vector problem and may even create the physical conditions leading to the problem.

Put simply, the ideal conditions for good irrigation management are similar to those which will discourage vector production in irrigated agriculture or will at least assist in vector control. This implies a minimum of unnecessary water surface, well constructed and maintained supply channels, effective, unimpeded drainage of excess water and efficient, economical water application. When the quality of irrigation water causes a departure from these conditions, there is increased risk of vector production.

There are four ways in which water quality may affect the size and species composition of the populations of disease vectors and nuisance insects:

- by creating soil conditions which extend water surfaces in area, or in duration;
- by requiring irrigation practices which also result in the extension of water surfaces in area, or duration;
- by modification of the aquatic flora or fauna; and
- by direct influence on the vector.

Adverse soil conditions, with low rates of infiltration, may arise when the irrigation water has very low salinity or a high sodium content relative to the calcium and magnesium content. This has the obvious effect of extending the time when irrigation water is standing in the field and also results in longer periods of stagnant water, following rainfall, outside the irrigation season. Where the intensity of land use under irrigation is relatively low, this may mean that the exposed water surface is even greater than the irrigated area and that the period of standing water is sufficient for a number of breeding cycles of vector and pest insects or for the proliferation of populations of snail intermediate hosts necessary for the development and multiplication of schistosome larvae.

When salinity is high, it may be necessary to supply irrigation at very short intervals so that the soil surface is often wet, and depressions will always contain water. When salt accumulation must be

corrected by leaching, this may call for the ponding of water in the field for periods of many days. In either case, with an inevitable carry-over period to complete drainage or drying out of low spots, there may be sufficient time for completion of the aquatic part of the mosquito life cycle (usually within two weeks under tropical conditions) and the production of a new generation of adults.

A problem which most commonly affects agricultural drains is that of growth stimulation of aquatic weeds due to excess nitrogen from fertilizers. This can also occur in irrigation canals where there is a mixing of the supply with agricultural runoff or with wastewater from domestic or food-processing sources. The associated issues of weed clearance and channel maintenance have been referred to earlier, but the presence of dense aquatic weeds and algal growth also introduces conditions which are suited to the development of some insect vectors, pest insects and snails. In addition, it makes control by chemicals such as larvicides and molluscicides more difficult, more expensive and less effective.

The use of chemicals in vector control and for the control of agricultural pests may be, in itself, a cause of degraded water quality where it creates problems for other water uses. Examples of this can be found in the damage to beneficial aquatic fauna such as fish cultivated for their protein value, deterioration of livestock water supplies and, most dangerous of all, the contamination of domestic water which, in many developing countries, is derived from the irrigation supply with minimum, or no treatment.

The use of domestic wastewater in irrigation can be an attractive way to raise crop yields, but it has been known to result in a dramatic increase in the breeding of mosquitoes. This led to a recent ban on wastewater re-use for rice irrigation in California (see Section 8.22).

Sometimes a change in water quality will have a marked impact on aquatic fauna other than the vector or pest species of primary concern. This can happen when water from different sources is used conjunctively, either by mixing or in sequence. If the affected organisms represent a food supply for the vector, it is likely to discourage the growth of vector populations. On the other hand, if the result is a suppression of species which are natural predators or competitors of the vector, an upsurge of vector populations is likely. In the case of a periodic quality change, as for seasonal groundwater used to supplement low-flow surface supply, the impact may be detrimental to either vector or predator or both. Experience from such examples suggests that vector species tend to be more resilient and to recover more quickly, with consequent progressive increase in their populations.

Direct influence of water quality on vector populations and species distribution is usually related to species preference. For mosquitoes, this ranges from fresh running water to brackish water, salt pools, mineral groundwater, water contaminated with domestic effluent and even to septic tanks and cesspools. Vector mosquitoes can be found within the whole range of these preferences, therefore the assessment of possible water quality impact on mosquito-transmitted diseases calls for a careful study of the actual and potential status of the diseases in the human population, the locally occurring mosquito species and the quality characteristics of the water. These characteristics may in fact vary with season and from place to place, even within a scheme, producing an extremely complex set of circumstances.

Snail intermediate hosts are fairly tolerant to water quality conditions which fall within the range of suitability for irrigation. The presence of calcium is advantageous to the snail whereas a low pH is not. There is often a snail preference for a sediment content and for some organic pollution and, where this latter is due to domestic effluent in the water, the risk of schistosomiasis transmission is evident within endemic areas.

It can be seen that the association between water quality and vector-borne diseases is both complex and specific to the site and the human population. Even the more limited relationship between water quality and the presence and production of vector and pest species is subject to many physical and biological influences. This section has therefore been restricted to a brief outline of some of the general issues to be taken into consideration where there is a possibility of a health

problem arising or being modified as a result of water quality characteristics in agricultural development. The subject of disease transmission through the re-use of wastewater is a separate and distinct issue on which there is already extensive literature and for which there are many guidelines and examples of national control and legislation. This has not therefore been included in the present text, but the following list of references contains information and references related to this problem in addition to that of vector-borne diseases. References include: Agency for International Development (1975); Mather (1984); Feachem et al. (1977); McJunkin (1982); Tillman (1981); WHO (1973); and WHO (1982).

As a further source of information, the reader may always direct enquiries to the World Health Organization, 1211 Geneva 27, Switzerland.

ANNEX II
GLOSSARY

BOTULISM: poisoning from ingesting botulin (Clostridium botulinum), which affects the central nervous system producing difficulty in swallowing, visual disturbances and respiratory paralysis.

BRONZING: reddish-brown discoloration of leaves or stalks indicating a nutrient deficiency.

CHISELLING: mechanical preparation of land leaving it in a rough, cloddy condition, which helps to control wind erosion during dry periods and assists infiltration when the rain starts, or irrigation.

CHLOROSIS: yellowing or bleaching of green portion of a plant, particularly the leaves. May be caused by disease organisms, nutrient deficiencies, or other factors, e.g. low temperatures.

CORROSION (ELECTROLYTIC): corrosion (of well screens, pump components, cases or pipes) due to electrolytic action induced by metals from which the units are manufactured (see ELECTROLYTIC PROCESS).

DENITRIFICATION: the reduction of nitrates to atmospheric nitrogen and oxides of nitrogen.

DISEASE VECTOR: the living transporter and transmitter of the causative agent of a disease.

DRAINAGE WELL: a well from which water is pumped in order to lower the water table.

DRIP IRRIGATION: form of localized irrigation whereby the water is emitted from a tube or pipe in drips or drops (see LOCALIZED IRRIGATION).

ELECTRICAL CONDUCTIVITY (ECe): of the saturation paste at 25°C. The property of a substance to transfer an electrical charge (reciprocal of resistance). Used for the measurement of the salt content of an extract from a soil when saturated with water. Measured in dS/m, mS/cm, or µS/cm.

ELECTROLYTIC PROCESS: a process whereby the conduction of electricity induces chemical changes leading to solution or melting of substances.

ENCEPHALITIS: inflammation of the brain. Can be due to enteroviruses and certain arboviruses which cause serious central nervous system diseases (e.g. encephalitis). Vectors: mosquitoes (Culex), sandflies, gnats, midges and ticks.

EVAPOTRANSPIRATION (ET): rate of water loss through transpiration from vegetation plus evaporation from the soil.

EXCHANGEABLE SODIUM PERCENTAGE (ESP): the degree of saturation of the soil exchange complex with sodium; it may be calculated by the formula:

$$\text{ESP} = \frac{\text{exchangeable sodium (me/100 g soil)}}{\text{cation exchange capacity (me/100 g soil)}}$$

GYPSIFEROUS SOIL: soils that contain at least a percent of gypsum, i.e. calcium sulphate ($CaSO_4.2H_2O$). The range varies widely, e.g. 1% in Argentina and Brazil, or 5% in Syria.

LARVICIDE: a substance that kills larval stages of insects.

LEACHING FRACTION (LF): that portion of the irrigation water entering the soil that effectively must flow through and beyond the root zone in order to prevent the build-up of salinity. LF indicates that the value must be expressed as a fraction (see LEACHING REQUIREMENT).

LEACHING REQUIREMENT (LR): that portion of the irrigation water entering the soil that effectively must flow through and beyond the root zone in order to prevent the build-up of salinity. LR can be expressed either as a fraction or percentage of irrigation water.

LOCALIZED IRRIGATION: irrigation systems which wet, in particular, the area of soil at the base of the plant. Umbrella term for other irrigation systems such as: trickle, drip, drop, daily flow, micro.

LODGING: the beating down of crops by wind or rain; the tendency of certain long-stalked gramineae to collapse owing to nutrient deficiency.

LYMPHATIC FILARIASIS: infection in humans caused by filarial worms. The vectors are culicine or anopheline mosquitoes. Water habitat at larval stage.

MALARIA: infection in humans caused by four different malarial parasites (Plasmodium) introduced into the human bloodstream by the bite of an infected mosquito (Anopheles sp.) Water habitat at larval stage.

MOISTURE RETENTION CURVE: a graph showing the relationship between the amount of water remaining in the soil at equilibrium as a function of the matric suction. It is also known as soil-moisture characteristic curve.

MOLLUSCICIDES: a substance that kills molluscs (generally chemical).

NECROSIS: death of plant tissue due to disease, nutrient deficiency, toxicity, or climatic conditions, e.g. frost.

ONCHOCERCIASIS: or 'river blindness', disease caused by the filarial worm, Onchocerca volvulus. The vectors are black-flies (Simulium sp.). Water habitat at larval stage.

OSMOTIC EFFECT: the force a plant must exert to extract water from the soil. The presence of salt in the soil-water increases the force the plant must exert.

OSMOTIC POTENTIAL: the additional energy required to extract and absorb water from a salty soil.

READILY AVAILABLE SOIL MOISTURE: the depth of water between field capacity and wilting point stored in the root zone and available to the plant.

RESIDUAL SODIUM CARBONATE: a value that indicates the sodium hazard in water due to the loss of calcium and magnesium ions from the water by their reaction with bicarbonate and carbonate ions.

ROOT ZONE: the area of the soil from which the roots of a crop extract water and nutrients.

RUMINANT ANIMALS: any artiodactyl mammal of the suborder Ruminantia, the members of which chew the cud and have a stomach of four compartments; any other cud-chewing animal, e.g. the camel.

SALINITY PROFILE: a diagramatic representation of zones of varying levels of salinity, as exposed in a cut section of a field.

SALT INDEX: concerning fertilizer salts and compound fertilizers; an index of the extent to which a given amount of fertilizer increases the osmotic pressure of soil solution.

SATURATION INDEX: an estimate of carbonate precipitation from irrigation water as a function of the degree of calcium carbonate saturation of the soil solution.

SCHISTOSOMIASIS (bilharziasis): a disease caused by infestation of the body with blood flukes of the genus Schistosoma. Vector: intermediate host, snails. Water habitat or waterassociated habitat.

SCHOONOVER GYPSUM REQUIREMENT TEST: a laboratory method of determining gypsum requirements of sodic soils; a method established by Mr. Schoonover.

SODIUM ADSORPTION RATIO (SAR): a ratio for soil extracts and irrigation water used to express the relative activity of sodium ions in exchange reactions with soil; expressed in me/l.

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

SOIL AGGREGATE: a single mass or cluster of soil consisting of many soil particles held together, such as a clod, prism, crumb or granule.

SOIL AMENDMENTS: a substance or material which improves soil by modifying its physical properties rather than by adding appreciable quantities of plant nutrients.

SOIL CRUSTING: soil crusts are formed as a result of compaction at the immediate surface due to an externally applied force. This force is supplied primarily by the impact of raindrops, and also by irrigation water, as the soil is wetted and the radiant energy of the sun dries the soil.

SOIL SOLUTION: the aqueous solution existing in equilibrium with a soil at a particular moisture tension.

SOIL-WATER: depth of water available in the root zone from earlier rain, snow, or irrigation which partly or fully meets the requirements of a crop.

SOIL-WATER POTENTIAL: the amount of work that must be done per unit quantity of pure water in order to transport reversibly and isothermally an infinitesimal quantity of water from a pool of pure water at a specified elevation, at atmospheric pressure, to the soilwater at the point under consideration. The total soil-water potential is the sum of gravitational matric and osmotic potentials.

SPECIFIC ION TOXICITY: any adverse effect from a salt constituent in the substrata on plant growth that is not caused by the osmotic properties of the substrata.

TRANSPIRATION: rate of water loss through the plant which is regulated by physical and physiological processes.

WATER AMENDMENTS: chemicals added to water in order to improve certain soil-water properties such as increasing infiltration rates by causing a change in the chemical composition of the soil-water complex.

ABBREVIATIONS

dS/m	deciSiemens per metre
kg/ha	kilogramme per hectare
me/l	milliequivalent per litre
mg/l	milligramme per litre
mm/hr	millimetre per hour

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ATTACHMENT G: ***Crop Yields as Affected by Salinity*****, in Agricultural Drainage - E.V. Maas and S.R. Grattan**

3 Crop Yields as Affected by Salinity

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I. INTRODUCTION

Drainage of irrigated lands is one of the requisites for sustaining agricultural productivity in a given region over the long term. Adequate drainage not only allows for better aeration in the crop root zone but provides a means by which salinity and toxic elements can be managed and controlled. The previous chapter in this publication addressed the influence of inadequate drainage on crop yields in terms of excess water and timeliness. The emphasis of this chapter is on: (i) how plants respond to salinity and toxic elements (i.e., Na^+, Cl^-, and B), (ii) the various factors that influence plant response to salinity, (iii) the extent to which salinity affects crop yields, and (iv) management strategies to maximize yields by controlling soil salinity. In each of these subsections, we have specified areas which require additional research. It is not our intent to provide a comprehensive review of the physiological effects of salinity on crop plants. This subject has been covered by others (Cheeseman, 1988; Gorham et al., 1985; Greenway & Munns, 1980; Läuchli & Epstein, 1990; Maas & Nieman, 1978; Munns, 1993; Poljakoff-Mayber & Lerner, 1994; Yeo, 1983).

II. SOURCE AND CAUSES OF SOIL SALINITY

All salts found in soils and waters originated from parent rock material that has undergone geochemical weathering. Over geologic time, primary minerals have reacted with water, O_2, and CO_2 to form secondary minerals and salts that were transported by water to oceans or depressions in the landscape. Inundation of large land masses by saline seas deposited sedimentary materials that have become the major source of salt in arid regions. The processes of weathering and the chemistry of salt-affected soils have been addressed by Jurinak and Suarez (1990).

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In coastal or delta regions, salination of soils may occur predominantly by salts that contaminate fresh water supplies by seawater intrusion. Seawater intrusion can impair groundwater quality when wells are overdrafted. Surface waters can be polluted when saltwater migrates inland up low-flowing fresh-water channels. Coastal agriculture also may be subjected to cyclic salts where saline aerosols are produced by violent wave activity during storms or high winds on the sea. These salts can move inland considerable distances but the most harmful effects occur on vegetation or crops grown close to the shore.

Salts, however, can be found in groundwater at relatively high concentrations without originating from the sea. The concentration and composition of groundwater is largely dependent upon the geochemical environment that the infiltrating water encounters en route to the groundwater. Salts that are contained in irrigation water, regardless of their source, can salinize agricultural land if the mass of salts that moves out of the root zone is less than the mass of salts entering the root zone. A favorable salt balance within the root zone must be maintained by adequate leaching. Disposal of drainage effluents must accompany adequate leaching.

In closed basins, salts may have been present in the soil long before irrigation was introduced to a region. Upon irrigation, saline water tables can develop in poorly drained areas in relatively short time periods (i.e., years). Even if good-quality water is used for irrigation, salination may occur from rising saline water tables. Rising water tables are a result of excessive leaching and are often associated with poor water-management practices.

The two processes described above: (i) salination from irrigation with saline water and (ii) salination from shallow saline water tables, are the most common cause of large-scale soil salination in irrigated agriculture. They are, of course, not mutually exclusive and often highly saline water tables can occur from or in association with saline irrigation water. Other processes of soil salination described by Tanji (1990) occur on a smaller scale and will not be discussed in this chapter.

III. PLANT RESPONSE TO SOIL SALINITY

The most common whole-plant response to salt stress is a general stunting of growth. As salt concentrations increase above a threshold level, both the growth rate and ultimate size of crop plants progressively decrease. However, the threshold and the rate of growth reduction vary widely among different crop species. Some crops, like the common bean[1] or strawberry, are highly sensitive and begin to exhibit injury symptoms and growth reductions at salt concentrations only twice that present in nonsaline soils. Other crops like barley, cotton, and sugarbeet, are nearly as tolerant as some halophytes which actually grow better in moderately saline environments.

Although salinity affects plants in many ways physiologically, overt injury symptoms seldom appear except under extreme levels of salt stress. Salt-affected plants usually appear normal, although they are stunted and may have darker

[1] Botanical names of crops mentioned in the text can be found in Tables 3–1 and 3–2.

green leaves which, on some plant species, are thicker and more succulent. Growth suppression seems to be a nonspecific salt effect that is directly related to the total concentration of soluble salts or osmotic potential of the soil water. Within limits, isosmotic concentrations of different combinations of salts cause nearly equal reductions in growth. On the other hand, single salts or extreme ion ratios are likely to cause specific ion effects, viz., ion toxicities or nutritional imbalances which cause even further yield reductions. For a discussion of the mechanisms of osmotic and specific ion effects, see Bernstein (1975) and Läuchli and Epstein (1990). Since saline soils in the field generally consist of a mixture of different salts, specific ion effects are minimal and osmotic effects predominate, particularly on annual crops or perennials grown as annuals (e.g., cotton). Woody fruit and nut crops, on the other hand, can accumulate Cl^- and/or Na^+ to toxic levels which cause leaf burn, necrosis, and defoliation. The onset and severity of injury is related to the rate of foliar accumulation. Some herbaceous crops, e.g., soybean, also are susceptible to ion toxicities, but most do not exhibit leaf injury symptoms even though some accumulate levels of Cl^- or Na^+ that cause injury in woody species.

When specific ion toxicities occur, the effects on yield are generally additive with the growth suppressive effects of osmotic stress; yet the growth-reducing contributions of each are difficult to quantify. The additive effect can be attributed to leaf damage and defoliation which further reduces the photosynthesizing area of a salt-stunted plant canopy. In some woody species, like grape, toxic effects may be dominant (Ehlig, 1960); in others, such as stone fruits, yield losses caused by toxicity may be comparable to those caused by osmotic stress (Bernstein et al., 1956).

With most crops, including tree species, yield losses from osmotic stress can be significant before foliar injury is apparent. Reports that citrus yield reductions occur without excessive accumulations of Cl^- or Na^+, and without any apparent toxicity symptoms indicate that the dominant effect is osmotic (Bingham et al., 1974; Bielorai et al., 1978, 1988; Levy et al., 1979; Cerdá et al., 1990; Dasberg et al., 1991). However, salts tend to accumulate in woody tissues over several years before toxic symptoms appear; consequently, the effects of leaf injury and loss can occur dramatically when the salts reach the leaves. In these instances, tree or vine tolerance to salinity may decrease over the years as injury caused by specific-ion toxicities becomes more acute.

The onset and timing of foliar injury may determine the extent of damage to crop yields. Injury that appears late in the season on annual crops may have little effect on yield. With tree crops that develop fruit yields over a 2-year period, foliar injury and leaf loss during both years will be more detrimental than injury that occurs only the 2nd year. Of course, continued salt stress will eventually damage the tree itself.

Salt tolerance studies on woody fruit and nut trees are scarce, presumably because of the long-term, complex nature of the research (Maas, 1992, 1993). Salinity stress imposed 1 year may have physiological and/or morphological effects on subsequent years. Furthermore, it is difficult to evaluate tree or vine response to salinity and account for dormant periods, changing climate throughout the year, and temporal and spatial changes in the salinity profile. Nevertheless, long-term research is needed to evaluate these factors.

While crop salt tolerance is based solely on yield, salinity adversely affects the quality of some crops while improving quality of others. By decreasing the size and/or quality of fruits, tubers, or other edible organs, salinity reduces the market value of many vegetable crops, e.g., carrot, celery, cucumber, pepper, potato, head cabbage and lettuce, and yam (Bernstein et al., 1951; Bernstein, 1964; Francois & West, 1982; Shannon, 1980). Rye grown on saline soils produces grain with poorer bread-baking quality (Francois et al., 1989). Salinity appears to have little effect on the quality of citrus fruit (Maas, 1993). Beneficial effects include increased sugar content of carrot (Bernstein & Ayers, 1953a) and asparagus (Francois, 1987), increased total soluble solids in tomato (Shalhevet & Yaron, 1973; Adams & Ho, 1989) and muskmelon (Shannon & Francois, 1978), and improved grain quality of durum wheat (Francois et al., 1986). Generally, however, beneficial effects of salinity are offset by decreases in yield.

A. Nutritional Imbalance

Besides causing specific toxic effects, salinity can induce elemental nutrient deficiencies or imbalances in plants. The specific effects vary among species and even among varieties of a given crop. The optimal concentration range for a particular nutrient-element in the soil solution depends on many factors, including salt concentration and composition (Grattan & Grieve, 1994). This is not surprising since salinity affects nutrient ion activities and produces extreme ion ratios (e.g., Na^+/Ca^{2+}, Na^+/K^+, Cl^-/NO_3^-, etc.) in the soil solution. Nutrient imbalances in the plant may result from the effect of salinity on: (i) nutrient availability, (ii) the uptake and/or distribution of a nutrient within the plant, and/or (iii) increasing the internal plant requirement for a nutrient element resulting from physiological inactivation (Grattan & Grieve, 1994).

A substantial body of information in the literature indicates that nutrient element acquisition by crops is reduced in saline environments. This, of course, depends on the nutrient element in question and the composition of the salinizing solution. The activity of a nutrient element in the soil solution decreases as salinity increases, unless, of course, the nutrient in question is part of the salinizing salts (e.g., Ca^{2+}, Mg^{2+}, or SO_4^{2-}). For example, phosphate availability is reduced in saline soils not only because the ionic-strength effect reduces the activity of phosphate, but also its concentration is controlled by sorption processes and by Ca-P minerals. Therefore P concentrations in many full-grown agronomic crops decrease as salinity increases (Sharpley et al., 1992). Indirectly, soil salinity can affect nutrient acquisition by severely reducing root growth. Reductions of 40 to 50% have been reported in root weight and lengths of citrus and tomato (Zekri & Parsons, 1990; Snapp & Shennan, 1992).

Nutrient uptake and accumulation by plants is often reduced under saline conditions as a result of competitive processes between the nutrient and a major salt species. Although plants selectively absorb K^+ over Na^+, Na^+-induced K deficiencies can develop on crops under salinity stress by Na salts (Janzen & Chang, 1987). On the other hand, Cl^- salts can reduce NO_3^- uptake and accumulation in crops even though this effect may not be growth limiting (Munns & Termaat, 1986).

Sodium-induced Ca^{2+} deficiences have been observed by many researchers when the Na^+/Ca^{2+} ratio in the solution, at a given salinity level, increases above

a threshold level. This is particularly true for many crops in the grass family (e.g., corn, sorghum, rice, wheat and barley) and striking differences have been observed among species and cultivars. Calcium deficiency may be related, at least in part, to Na^+'s effect on Ca^{2+} distribution within the plant. Some researchers found Na^+ to inhibit the radial movement of Ca^{2+} from the root epidermis to the root xylem vessels (Lynch & Läuchli, 1985) while others found it to inhibit Ca^{2+} transport to meristematic regions and developing leaves (Maas & Grieve, 1987; Grieve & Maas, 1988). Salinity-induced Ca^{2+} deficiency also has been observed on crops from different families such as blossom-end rot in tomato and bell pepper and black heart in celery (Geraldson, 1957).

Other evidence indicates that salinity may cause some physiological inactivation of phosphate, thereby increasing the plant's internal requirement for this element (Awad et al., 1990). They found that when sodium chloride concentrations were increased from 10 to 100 m*M*, P concentration in the youngest mature tomato leaf necessary to achieve 50% yield nearly doubled. Moreover, at any given leaf P concentration, foliar symptoms of P deficiency increased with increased sodium chloride salinity. It would not be surprising to find similar relationships involving other crops or even other nutrients.

IV. PARAMETERS INFLUENCING PLANT RESPONSE TO SALT STRESS

Although crop yields are a function of salt concentrations within the root zone, it must be recognized that this relationship is influenced by interactions between salinity and various soil, water, and climatic conditions. While other environmental stresses may limit crop yield, they may increase, decrease, or have no effect on the apparent salt tolerance of the crop. It is important, therefore, that the effects of any interacting factor be compared on the basis of relative crop yield. This point is illustrated by the types of possible interactions shown in Fig. 3–1. If the response to salinity is proportionately the same when another factor is limiting as when it is adequate, i.e., where the absolute yields in both cases are decreased by the same percentage, the relative tolerance would be the same (Type A). If salinity decreases yields by the same absolute amounts under both adequate and limiting conditions, a crop may appear relatively less tolerant under the suboptimal condition (Type B). However, if yield is severely limited by some suboptimal condition, e.g., inadequate soil fertility, a crop may appear relatively more tolerant than it would if it were grown with adequate fertility (Type C) because the effects of salinity on absolute yield cannot be as great as when fertility is adequate. The yield response relationships shown in Fig. 3–1 are idealized to represent only the range over which yield is linearly responsive to salinity. Actual salinity response curves usually follow a sigmoidal relationship.

If reductions in relative yield are independent of differences in actual yield caused by differences in soil conditions and properties, irrigation practices, climate, and other variables, a relative yield vs. salinity response curve gives a useful expression of salt tolerance. Some of the factors that can affect salt tolerance are discussed below.

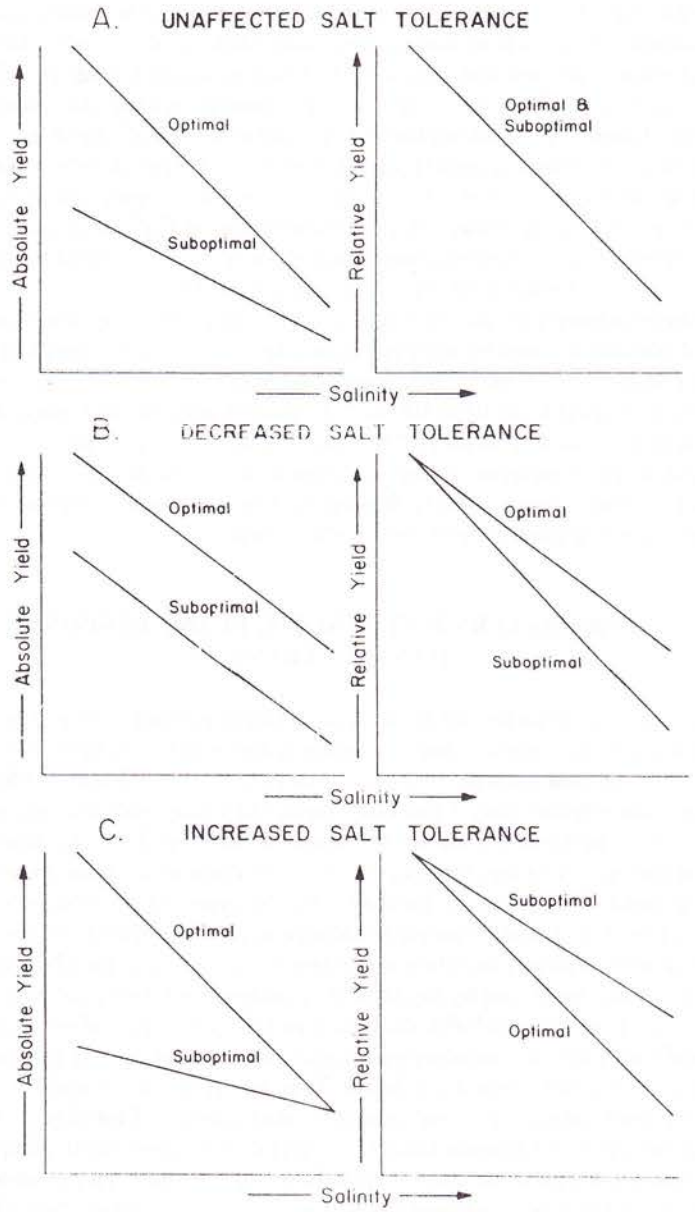

Fig. 3–1. Types of interactions between salinity and other variables such as soil fertility on absolute and relative yields. Relative yields under nonsaline conditions are plotted as 100% for both fertility levels [adapted from Bernstein et al. (1974)]: (*A*) independent effects of salinity and fertility at optimal and suboptimal levels of fertility, (*B*) decreased salt tolerance at suboptimal levels of fertility, (*C*) increased salt tolerance at suboptimal levels of fertility.

A. Edaphic Conditions

1. Salt Constituents

All soils and irrigation water contain salts. The major salinizing cations are Na^+, Ca^{2+} and Mg^{2+}, the major salinizing anions are Cl^-, SO_4^{2-} and HCO_3^-. However, the concentration and composition of salts vary among locations and among water sources. Other ions and elements are often present at much lower concentrations. These can affect crop production (e.g., B), crop quality (Se and Mo), or opportunities for drainage disposal (NO_3^-, B, Se, As, U, Mo, etc.) (Tanji, 1990).

2. Salt Distribution in the Soil Profile

Except for controlled experimental conditions, soil salinity is seldom constant with time or uniform in space. Depending upon the extent of leaching and drainage, salt distribution may be rather uniform in the soil and change relatively little with depth or it may be highly nonuniform with salinities varying from concentrations approximately that of the irrigation water near the soil surface to concentrations many times higher at the bottom of the root zone.

The method of irrigation is another major factor controlling the distribution of salt in the soil profile (Oster et al., 1984) and is discussed later in this chapter. If a saline water table exists within 1.5 m of the soil surface, salts may be transported upward by capillary flow. In this case, the soil salinity profile may be inverted with the highest concentrations at the soil surface.

Salinity also increases between irrigations as the soil water is evaporated. Consequently, the plant must respond to salt concentrations that differ severalfold within its root zone and that are continually changing. Root growth and distribution are not only affected by soil water content and the type of irrigation, but by variable salinity as well (Bernstein & Francois, 1973b; Alva & Syvertsen, 1991). Snapp and Shennan (1992) found that salinity enhanced root senescence in one tomato cultivar, although another was unaffected. Unfortunately, hardly any quantitative data are available on root development in saline soils and this information is crucial.

Exactly how plants respond to salinity that varies spatially and temporally in the soil profile is still a subject of considerable debate. To relate crop yields to variable levels of soil salinity, Rhoades and Loveday (1990) recommend using a linear, depth- and time-averaged salinity in the root zone for conventional irrigation, i.e., where the soil is allowed to dry out between irrigations, and a water uptake-weighted salinity in the root zone for high-frequency irrigation.

3. Soil Water Content

Salt-affected crops often must contend with water deficits or excess as well. Therefore, actual crop performance during the growing season is related to how the plant responds to both salinity and water stress. In flooded or poorly drained soils, the overall diffusion of O_2 to roots is reduced, thereby limiting root respiration and plant growth (Sharpley et al., 1992). When the root zone is saturated with saline water, the combined effects of salinity and O_2 deficiency can adversely affect seed germination (Aceves-N. et al., 1975), selective ion transport

processes in the plant (Drew et al., 1988), and shoot growth (Aubertin et al., 1968).

Water deficit, at least to some degree, is practically unavoidable under field conditions since the soil-water content varies temporally and spatially throughout the season. Exactly how the plant responds to the combination of stresses from salinity and water deficit remains unresolved (Meiri, 1984). Obviously the combination of stresses is more damaging than either one alone, but are they additive or antagonistic? Quantifying the growth-limiting contribution of each is difficult since both change over time and space. Water-deficit stress may predominate in the upper root zone while salt stress may predominate in the lower root zone.

Wadleigh and Ayers (1945) first demonstrated that bean plants responded to the additive combination of water deficit and salt stress. More recently, however, Meiri (1984) concluded from data collected by Parra and Romero (1980) that matric potential affected bean shoot growth more than did osmotic potential. Although thermodynamically, matric and osmotic components are additive, there are kinetic factors (i.e., water flow) that must be considered. For example, plant response to these stresses under conditions of low evaporative demand is likely to be different than that observed under high evaporative demand since matric and not osmotic potential dominate control of water flow from soil to roots. The magnitude of the difference may be related to differences in evaporative demand and root-length density.

Regardless of how plants respond to integrated stress, they presumably do better when grown on saline soils if water deficit stress is minimized. However, increasing irrigation frequency does not necessarily improve yields of salt-stressed crops (Bresler & Hoffman, 1986; Shalhevet et al., 1982, 1986). Salt-stressed plants are smaller and grow slower than nonsalt-stressed plants, and require less water over a given time. Consequently, salt-stressed plants deplete a smaller percentage of available soil water than nonsaline plants, so they are less responsive to frequent irrigations. Therefore, increased irrigation frequency benefits salt-stressed plants only when it reduces water stress, maintains the salt concentration in the soil solution below growth-limiting levels and does not contribute to additional stresses such as O_2 deficit or root disease (e.g., phytophthora). As Wadleigh and Ayers (1945) concluded a half century ago, it is not that salt-stressed plants should necessarily be irrigated more frequently, but rather that they should be irrigated at lower soil-water depletions.

4. Soil Biota

Full coverage of the interactions of salinity and soil flora and fauna is clearly beyond the scope of this chapter. However, the importance of soil organisms cannot be ignored. *Rhizobium* spp., which are integral to legume production, seem more salt tolerant than their host plants, but evidence indicates that nodulation and N_2 fixation by some crops are impaired by salinity (Läuchli 1984). Growth of several legumes was reduced more when grown symbiotically than with N fertilization. Some investigators have suggested that mycorrhizal symbioses improve the ability of some crops to tolerate salt by improving P nutrition (Hirrel & Gerdemann, 1980; Ojala et al., 1983; Poss et al., 1985).

Although salinity doesn't specifically cause plant diseases, salt-stressed plants may be predisposed to infection by soil pathogens. Salinity has been reported to increase the incidence of phytophthora root rot in chrysanthemum (MacDonald, 1982), citrus (Blaker & MacDonald, 1986), and tomato (Snapp et al., 1991). The combined effects significantly reduced fruit size and yield of tomato (Snapp et al., 1991). Wetter soil under salt-stunted plants may contribute to increased susceptibility to fungal diseases. Inadequate drainage could exacerbate this condition.

5. Soil Physical Condition

Other suboptimal soil conditions also can affect the apparent salt tolerance of crops. For example, soils with poor structure or impermeable layers could restrict root growth as well as influence water and salt distribution in the soil. Crusting at the soil surface acts as a physical barrier for emerging seedlings and can lead to poor stand establishment particularly if the young seedlings are already weakened by salt stress.

6. Soil Fertility

In irrigated agriculture, fields are usually fertilized to achieve maximum productivity. Sometimes fertilizer applications are inadequate or even omitted because of cost or availability. If crops are grown on low fertility soils, they may seem more salt tolerant than those grown with adequate fertility. The reason is that fertility, not salinity, is the primary factor limiting plant growth. Proper fertilizer applications would increase yields whether the soil was saline or not, but proportionately more if it were nonsaline. The results of Bernstein et al. (1974) indicate that the effects of salinity and nutritional stresses tend to be additive, provided that neither of these stresses are extreme. When yields are limited similarly by salinity and infertility, the effects of decreasing salinity or increasing fertility will give similar benefits. However, if yields are reduced much more by one factor than the other, alleviating the most severe condition will increase yield more than alleviating the less restrictive condition.

Therefore, one must be careful in interpreting salinity x fertility studies in terms of whether fertilizer additions increase or decrease crop salt tolerance. Response functions are based on relative crop yield as salinity increases from nongrowth-limiting to severely growth-limiting levels (Maas, 1990). Although suboptimal soil fertility may be the most growth-limiting factor at low salinity, salt stress may be the most growth limiting at higher salinity levels with the same level of fertility (Grattan & Grieve, 1994). Therefore, depending on the severity of salt stress, fertilizer additions may increase or decrease crop salt tolerance.

Although crop salt tolerance is expressed on a relative basis, actual yields must be considered in evaluating the benefits of fertilizer. For example, fertilizer additions may decrease crop salt tolerance, but it still may be economically advantageous to fertilize if absolute yields are increased. However, unless salinity causes specific nutritional imbalances, fertilizer applications exceeding that required under nonsaline conditions have rarely been beneficial in alleviating

growth inhibition by salinity. Most studies indicate that excess N, P, and K applications have little effect or reduce salt tolerance (Grattan & Grieve, 1994); however, Ravikovitch and Yoles (1971) found that N, P, or both, seemed to increase the salt tolerance of millet and clover.

B. Climate and Air Quality

Climatic conditions probably influence plant response to salinity as much if not more than any other factor. Most crops can tolerate greater salt stress if the weather is cool and humid than if it is hot and dry. The combined effects of salinity and conditions of high evaporative demand, whether caused by high temperature, low humidity, wind, or drought, are more stressful than salinity alone. Studies on several crops including alfalfa, bean, beet, carrot, cotton, onion, squash, strawberry clover, saltgrass, and tomato have shown that salinity decreased yields more when these crops were grown at higher temperatures (Ahi & Powers, 1938; Magistad et al., 1943; Hoffman & Rawlins, 1970). Yields of many crops also are decreased more by salinity when atmospheric humidity is decreased. Experiments indicate that barley, bean, corn, cotton, onion, and radish were more sensitive to salt at low than high humidity; however, the tolerances of beet and wheat were not markedly affected by humidity (Hoffman & Rawlins, 1970, 1971; Hoffman et al., 1971; Nieman & Poulsen, 1967).

Because climate has a pronounced effect on plant response to salinity, the time of year salt tolerance experiments are conducted could affect the outcome. For example, if the salt tolerance of cool-season vegetable crops were assessed in hot, dry climates, results may underestimate their actual salt tolerance in their normal environment which is cooler with a lower evaporative demand (Magistad et al., 1943; Hoffman & Rawlins, 1970).

Yields of many crops are adversely affected by air pollutants (Heck et al., 1982). A number of studies have shown that O_3, a major air pollutant, decreases the yield of some crops more under nonsaline than saline conditions (Bytnerowicz & Taylor, 1983; Hoffman et al., 1973, 1975; Maas et al., 1973; Ogata & Maas, 1973). Although this interaction was not demonstrated for field-grown alfalfa (Olszyk et al., 1988), the presence of air pollutants should not be overlooked when evaluating the response of crops to soil salinity stress.

Expected increases in atmospheric carbon dioxide concentrations (Kimball, 1990) also may affect how crops respond to salinity. Schwarz and Gale (1984) reported that enhanced carbon dioxide levels increased the salt tolerance of bean, corn, *Xanthium strumarium,* and *Atriplex halimus.* Although the carbon dioxide concentration used in their study was extremely high (2500 μL/L), a similar result was observed for rose (*Rosa hybrida*) (Zeroni & Gale, 1989) and alfalfa (C. Oren and J. Gale, unpublished data, see Gale & Zeroni, 1985) at concentrations that were only two and four times that of ambient control levels.

There may be agronomic as well as ecological value in conducting salinity experiments at differential carbon dioxide levels to compare how plants with different photosynthetic pathways [i.e., C_3, vs. C_4, vs. CAM (Crassulacean acid metabolism)] perform relative to each other.

C. Plant Parameters

1. Stage of Growth

Crop sensitivity to soil salinity continually changes during the growing season. Most crops are tolerant during germination but the young developing seedlings are susceptible to injury during emergence from the soil and during early development. Once established, most plants generally become increasingly tolerant during later stages of growth. One of the primary effects of salt stress is that it delays germination and emergence. Delays could be fatal if the emerging seedlings, already weakened by salt stress, encounter additional stresses, such as water stress, extreme temperature fluctuations and/or soil crusting. Because of evaporation at the soil surface, the salt concentration in the seed bed is often greater than at deeper depths. Consequently, the juvenile roots of emerging seedlings are exposed to greater stress than indicated by salinity values averaged over deeper depths as determined by the usual soil sampling methods. The loss of plants during this crucial phase may reduce the plant population density to sub-optimal levels which would significantly reduce yields. Miyamoto et al. (1985) suggest that poor emergence is the result of hypocotyl injury and mortality caused by high salt concentrations at the soil surface.

Salt tolerance during emergence differs considerably among crops but does not correlate well with tolerance parameters expressed in terms of yield response functions. Of course, different criteria are used to evaluate plant responses to salinity during these different stages of plant development. Tolerance at emergence is based on survival, whereas tolerance after emergence is based on decreases in growth or yield.

Most published data indicate that plants are more sensitive to salinity during the seedling stage than during germination, e.g., wheat (Ayers et al., 1952; Maas & Poss, 1989a; Udovenko & Alekeseeva, 1973) barley (Ayers et al., 1952), cotton (Abul-Naas & Omran, 1974), rice (Heeman et al., 1988; Kaddah, 1963; Pearson et al., 1966), senna (Ayoub, 1977), tomato (Dumbroff & Cooper, 1974), corn (Maas et al., 1983), and peanut (Shalhevet et al., 1969). Seedlings also are more sensitive than older plants. Greenhouse experiments on corn and wheat indicated that dry matter yields of 3-wk-old plants were reduced by concentrations of salt that were lower than the salinity thresholds for grain production (Maas et al., 1983; Maas & Poss, 1989a). Similar results have been obtained for several cultivars of rice (Heeman et al., 1988).

Reliable data on the salt tolerance of crops during emergence and seedling growth are extremely limited (Maas & Grieve, 1994). Although salt stress may delay emergence, the final emergence percentage for most crops is not affected if salt concentrations remain at or below the tolerance threshold for mature yields. No systematic evaluation of the tolerance of crop seedlings grown under actual or simulated field conditions has ever been undertaken. Clearly, more research is needed to better understand how crops respond to integrated stresses they encounter between germination and emergence.

Although corroborating data are limited, it is generally agreed that most plants become increasingly tolerant as they grow older. The earlier plants are stressed, the greater the reduction in vegetative growth (Kaddah & Ghowail, 1964; Lunin et al., 1961, 1963). For determinate plants, the proportion of biomass that is

subject to growth reduction becomes less the later they are stressed. Of course, the duration of stress also would be shorter. In an experiment where salinity treatments were of equal duration, it was found that the later cowpea, an indeterminate crop, was stressed, the less vegetative growth was reduced (Maas & Poss, 1989b). Increased tolerance with age also has been observed in asparagus, a perennial that was much more tolerant after the 1st year's growth (Francois, 1987).

In sand culture experiments designed to test the relative effects of salt stress at different stages of growth on grain production, sorghum (Maas et al., 1986), wheat (Maas & Poss, 1989a), and cowpea (Maas & Poss, 1989b) were most sensitive during the vegetative and early reproductive stages, less sensitive during flowering, and least sensitive during the grain-filling stage. Salt stress during spike or panicle differentiation hastened spikelet development and markedly reduced the number of spikelets in wheat (Maas & Grieve, 1990). The reduction in grain-bearing spikelets, however, was partially offset by an increase in the number of seeds per spikelet (Grieve et al., 1992). Heeman et al. (1988) found that the reduction in panicle yield of rice was highly correlated with the reduction in number of florets per panicle.

With cereal crops, it appears that the most serious effect of salt stress during the vegetative and early reproductive stage is the suppression of tiller formation. Results with two wheat cultivars showed that salt stress eliminated most secondary tillers and greatly reduced the number of coleoptilar and primary tillers (Maas et al., 1994). Primary tillers on the first and second leaves were the least susceptible to salt stress. Yield decreases result mainly from the reduced number of spike-bearing tillers and less from decreases in seed per spike (Maas & Grieve, 1990; Maas et al., 1996).

The results suggest that cereals become increasingly tolerant after the booting stage and are not particularly sensitive during flowering. However, conflicting data have been obtained for rice. Pearson and Bernstein (1959) found that rice was sensitive during pollination and fertilization, whereas Kaddah et al. (1973, 1975) did not. One explanation of this discrepancy may be found in the work of Akbar and Yabuno (1977). They found that salinity caused panicle sterility in some rice varieties and not in others and suggested that resistance to panicle sterility was genetically controlled. More recently, Khatun and Flowers (1995) reported salinity affected grain yield more than that of vegetative growth. They attributed the effect to delayed flowering, a decrease in the number of productive tillers and fertile florets per panicle, and weight per grain (Khatun et al., 1995). They too concluded that genotypic variation governs the extent to which salinity affects reproductive physiology and development in rice.

2. Varieties and Rootstocks

Salt tolerance data for most crop species are based on the test results of one or two varieties or cultivars. Most commercial cultivars within a species have similar tolerances, perhaps because they were developed under nonsaline conditions and were not selected to endure salt stress. Nevertheless, it must be recognized that significant varietal differences in salt tolerance do occur for some species (Shannon & Noble, 1990). It is not always clear, however, if the differences reflect differences in salt tolerance or differences in adaptation to the particular climatic or nutritional conditions under which the crops were tested.

The capability of fruit tree and vine crops to tolerate soil salinity is highly dependent upon the rootstocks. Their tolerance seems to be related primarily to the capability of different rootstocks to regulate the uptake of Na^+ and/or Cl^-. This factor will be discussed in more detail below.

D. Cultural Practices

1. Irrigation Methods

The method of irrigation can affect the crop's response to salinity. The irrigation method: (i) influences the salt distribution in the soil (ii) determines whether leaves will be subjected to wetting and (iii) determines the ease at which high soil-water potentials can be achieved (Shalhevet, 1984). Since irrigation methods that maintain a higher soil-water potential reduce the time-averaged salt concentration in the soil-water, they allow for optimal plant performance.

With pressurized systems, such as drip and sprinkler, small applications of water can be applied to fields uniformly, unlike surface irrigation methods such as furrow, basin or flood. Surface irrigation systems require some minimum quantity of water to enable uniform applications of water over the field. This minimum quantity may be in excess of the yield threshold soil-water depletion, thereby resulting in unnecessary drainage losses. Therefore, pressurized systems (sprinkler, drip, etc.) are more conducive for light, uniform irrigations.

Although irrigating at a lower soil-water depletion may be desirable to maintain a favorable soil-water environment, use of sprinkler irrigation to achieve this creates an additional problem. Salts in the irrigation water can be readily absorbed by wetted foliage and cause foliar injury. This subject will be addressed in more detail later in this section.

In light of this discussion, it is not surprising that crop salt-tolerance has been found to vary under different irrigation methods (Bernstein & Francois, 1973b, 1975; Meiri et al., 1982) where crop performance was best under drip irrigation, and worst under sprinkler irrigation.

2. Seed Bed Arrangements

It has been known for decades that the configuration of the seed bed and the position of the seed can influence germination and stand establishment in salt-affected fields that are furrow-irrigated (Bernstein et al., 1955a; Bernstein & Fireman, 1957). Seeds with flat-topped, single-row bed configurations are particularly susceptible to salt injury because salts accumulate in bed centers (Bernstein et al., 1955a). On the other hand, sloping beds create the most favorable condition since a majority of the salts are carried past the seed along with the wetting front en route to the highest point in the bed. Bernstein and Fireman (1957) listed several other management strategies that could be employed to minimize salt accumulation in the seed environment of furrow-irrigated crops including: (i) maintaining a high water level in the furrow, (ii) planting single or double rows on sloping beds, (iii) planting in "V" depression on double-row, flat-topped beds, and (iv) irrigating in alternate furrows in flat-topped beds that are planted with a single-row. Other strategies are discussed by Pasternak and DeMalach (1994).

Salt distribution patterns, such as those described above, are related in part to the net direction of water flow in the soil. Salt accumulation is lowest at the

point in the soil where irrigation water contacts the soil but increases in the direction of soil water flow. Water moves in the direction where it is transpired or evaporated thereby concentrating salts in areas where this occurs (Kruse et al., 1990). Oster et al. (1984) have illustrated salt accumulation patterns under furrow, sprinkler, drip, and subsurface drip irrigation methods. Subsurface drip irrigation practice can create a unique salt accumulation pattern where salts accumulate in the soil above the drip line. Plant roots encounter unexpected salination when rain moves salts that accumulated at the soil surface back into the root zone.

3. Plant Population Density

Salt tolerance data are generally expressed in terms of yield per plant. If the number of plants per unit land area is constant, the data are valid when expressed on a land area basis as well. Salt tolerance tests at the U. S. Salinity Laboratory are designed to minimize effects of salinity on plant stands. Salinity treatments are initiated after seedlings are fully established and plant mortality is usually minimal thereafter. An important factor in designing salt tolerance experiments is the plant population density. Usually planting densities similar to commercially accepted practices are used but this may inadvertantly bias yield response to saline treatments. If salinity reduces plant growth sufficiently to reduce canopy cover, planting densities appropriate for nonsaline soils may be too low for saline soils and may limit their potential yields per unit area. Higher planting densities would insure canopy closure and increase the capture of solar energy. Some crops benefit further by the fact that salinity can increase the harvest index by reducing vegetative growth more than it reduces seed yields. However, where the vegetative organ is the marketable product, salinity's effect on size or quality may affect its marketability, e.g., smaller head size in lettuce (Shannon, 1980) or reduced petiole length in celery (Francois & West, 1982).

Experiments on cotton (Francois, 1982; Keren et al., 1983) and wheat (L. E. Francois, 1994, personal communication) have shown that yields can be significantly increased on saline soils by increasing the plant population density. The higher planting density in wheat offset the loss of productive tillers and yields were maintained or even increased. These results clearly show that plant population density can significantly influence salt tolerance data expressed per unit land area. An economic analysis indicates that it could also have a substantial impact on profits and the optimal quantities and qualities of irrigation water (Feinerman, 1983).

V. CROP YIELD RESPONSE FUNCTIONS

The salt tolerance of a crop can best be described by plotting its relative yield as a continuous function of soil salinity. For most crops this response function follows a sigmoidal relationship. However, some crops may die before the seed or fruit yields decrease to zero thus eliminating the bottom part of the sigmoidal curve. Maas and Hoffman (1977) proposed that this response curve could be represented by two line segments: one, a tolerance plateau with a zero slope; and the second, a concentration-dependent line whose slope indicates the yield reduction per unit increase in salinity. Figure 3–2 shows the two-piece model fit-

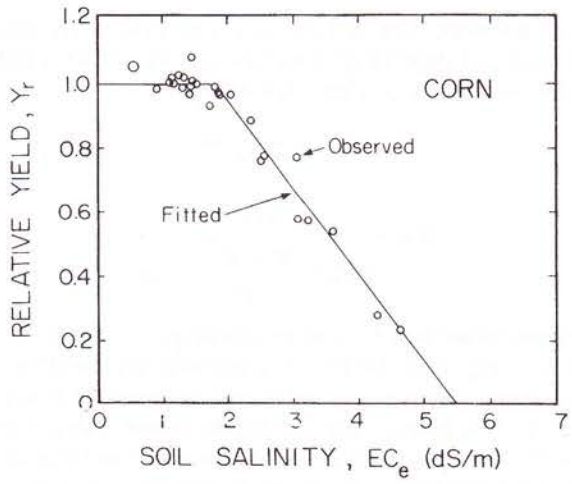

Fig. 3–2. The piecewise linear response function fitted to actual yield data obtained from corn [data from Hoffman et al. (1983)].

ted to actual grain yield data obtained in a salt tolerance experiment on corn. The point at which the two lines intersect designates the "threshold," i.e., the maximum soil salinity that does not reduce yield below that obtained under nonsaline conditions. This two-piece linear response function provides a reasonably good fit for commercially acceptable yields plotted against the electrical conductivity of the saturated-soil extract (EC_e). Electrical conductivity of the saturated-soil extract is the traditional soil salinity measurement with units of decisiemens per meter (1 dS m^{-1} = 1 mmho cm^{-1}). For soil salinities exceeding the threshold of any given crop, relative yield (Y_r) can be estimated with the following equation

$$Y_r = 100 - b(EC_e - a) \quad [1]$$

where a = the salinity threshold expressed in decisiemens per meter; b = the slope expressed in percentage per decisiemens per meter; EC_e = the mean electrical conductivity of a saturated-soil extract taken from the root zone.

The two-piece linear response function also is reasonably accurate when salinity is expressed in terms of the osmotic potential of the soil solution at field capacity (OP_{fc}). When the OP_{fc} is known, yield responses can be determined as a function of the osmotic stress that the plants experience. For osmotic potentials exceeding the threshold of a crop

$$Y_r = 100 - B(OP_{fc} - A) \quad [2]$$

where A = the salinity threshold expressed in bars; B = the slope expressed in percentage per bar; and OP_{fc} = osmotic potential of the soil water extracted from the root zone at field capacity. Equation [2], like Eq. [1], is linear even though OP_{fc} is not a linear function of EC_e. The deviation from linearity is small, however, and relative yields calculated from Eq. [2] are within 1 to 2% of those calculated from

Eq. [1]. The salt tolerance data in the subsequent sections are given in terms of EC_e. Threshold (A) and slope (B) parameters in terms of OP_{fc} can be determined from the EC_e data with the following relationships

$$A = -0.725a^{1.06} \quad [3]$$

$$B = \frac{100}{-0.725\dfrac{100 + ab^{1.06}}{b} - A} \quad [4]$$

These equations are based on the relationship, $OP_{fc} = -0.725\ EC_e^{1.06}$ which was obtained from Fig. 6 of the USDA Handbook no. 60 (U.S. Salinity Lab., 1954) after converting osmotic pressure in atmospheres at 0°C to osmotic potential in bars at 25°C. It is further assumed that the soluble salt concentration in the soil water at field capacity is twice that in the saturated-soil extract.

The threshold and slope concept has its greatest value in providing general salt tolerance guidelines for crop management decisions. Farmers need to know the soil salinity levels that begin to reduce yield and how much yield will be reduced at levels above the threshold. However, more precise plant response functions would be advantageous for crop simulation modeling. van Genuchten and Hoffman (1984) have described several nonlinear models that more accurately describe the sigmoidal growth response of plants to salinity.

The computer programs for these models were developed and documented by van Genuchten (1983). One of these models takes the form

$$Y_r = Y_m/[1 + (c/c_{50})^p] \quad [5]$$

where Y_m is the yield under nonsaline conditions; c is the average root zone salinity; c_{50} is the average root zone salinity that reduces yield by 50%; and p is an empirical constant. Values for root zone salinity, c and c_{50} can be expressed in terms of either EC_e or OP_{fc}. Like the two-piece linear model, this sigmoidal model only requires two parameters to describe the response curve, the c_{50} and p values.

VI. SALT TOLERANCE DATA

A. Herbaceous Crops

Table 3–1 lists threshold and slope values for 81 crops in terms of EC_e. Most of the data were obtained where crops were grown under conditions simulating recommended cultural and management practices for commercial production. Consequently, the data indicate relative tolerances of different crops grown under different conditions and not under some standardized set of conditions. Furthermore, the data apply only where crops are exposed to fairly uniform salinities from the late seedling stage to maturity. Where crops have particularly sensitive stages, the tolerance limits are given in the footnotes.

Table 3–1. Salt tolerance of herbaceous crops.[†]

Crop			Salt tolerance parameters			
Common name	Botanical name[‡]	Tolerance[§] based on	Threshold[¶] (EC_e)	Slope	Rating[#]	References
			dS/m	% per dS/m		
		Fiber, grain, and special crops				
Artichoke, Jerusalem	*Helianthus tuberosus* L.	Tuber yield	0.4	9.6	MS	Newton et al., 1991
Barley[††]	*Hordeum vulgare* L.	Grain yield	8.0	5.0	T	Ayers et al., 1952; Hassan et al., 1970a
Canola or rapeseed	*Brassica campestris* L. [syn. *B. rapa L.*]	Seed yield	9.7	14	T	Francois, 1994a
Canola or rapeseed	*B. napus* L.	Seed yield	11.0	13	T	Francois, 1994a
Chick pea	*Cicer arietinum* L.	Seed yield	—	—	MS	Manchanda & Sharma, 1989; Ram et al., 1989
Corn[§§]	*Zea mays* L.	Ear FW	1.7	12	MS	Bernstein & Ayers, 1949b (p. 41–42); Kaddah & Ghowail, 1964
Cotton	*Gossypium hirsutum* L.	Seed cotton yield	7.7	5.2	T	Bernstein, 1955 (p. 37–41), 1956 (p. 33–34); Bernstein & Ford, 1959a (p. 34–35)
Crambe	*Crambe abyssinica* Hochst. Ex R. E. Fries	Seed yield	2.0	6.5	MS	Francois & Kleiman, 1990
Flax	*Linum usitatissimum* L.	Seed yield	1.7	12	MS	Hayward & Spurr, 1944
Guar	*Cyamopsis tetragonoloba* (L.) Taub.	Seed yield	8.8	17	T	Francois et al., 1990
Kenaf	*Hibiscus cannabinus* L.	Stem DW	8.1	11.6	T	Francois et al., 1992
Millet, channel	*Echinochloa turnerana* (Domin) J. M. Black	Grain yield	—	—	T	Shannon et al., 1981
Oat	*Avena sativa* L.	Grain yield	—	—	T	Mishra & Shitole, 1986; USSL[‡‡]

Table 3–1. Continued.

Crop		Tolerance[§] based on	Salt tolerance parameters			References
Common name	Botanical name[‡]		Threshold[¶] (EC_e)	Slope	Rating[#]	
			dS/m	% per dS/m		
Peanut	*Arachis hypogaea* L.	Seed yield	3.2	29	MS	Shalhevet et al., 1969
Rice, paddy	*Oryza sativa* L.	Grain yield	3.0[¶¶]	12[¶¶]	S	Ehrler, 1960; Narale et al., 1969; Pearson, 1959; Venkateswarlu et al., 1972
Roselle	*Hibiscus sabdariffa* L.	Stem DW	—	—	MT	El-Saidi & Hawash, 1971
Rye	*Secale cereale* L.	Grain yield	11.4	10.8	T	Francois et al., 1989
Safflower	*Carthamus tinctorius* L.	Seed yield	—	—	MT	Francois & Bernstein, 1964b
Sesame[##]	*Sesamum indicum* L.	Pod DW	—	—	S	Yousif et al., 1972
Sorghum	*Sorghum bicolor* (L.) Moench	Grain yield	6.8	16	MT	Francois et al., 1984
Soybean	*Glycine max* (L.) Merrill	Seed yield	5.0	20	MT	Abel & McKenzie, 1964; Bernstein et al., 1955b (p. 35–36); Bernstein & Ogata, 1966
Sugarbeet[†††]	*Beta vulgaris* L.	Storage root	7.0	5.9	T	Bower et al., 1954
Sugarcane	*Saccharum officinarum* L.	Shoot DW	1.7	5.9	MS	Bernstein et al., 1966; Dev & Bajwa, 1972; Syed & El-Swaify, 1972
Sunflower	*Helianthus annuus* L.	Seed yield	4.8	5.0	MT	Cheng, 1983; Francois, 1996
Triticale	*X Triticosecale* Wittmack	Grain yield	6.1	2.5	T	Francois et al., 1988
Wheat	*Triticum aestivum* L.	Grain yield	6.0	7.1	MT	Asana & Kale, 1965; Ayers et al., 1952; Hayward & Uhvits, 1944 (p. 41–43)

Table 3–1. Continued.

Wheat (semidwarf)[‡‡‡]	*T. Aestivum* L.	Grain yield	8.6	3.0	T	Francois et al., 1986
Wheat, Durum	*T. Turgidum* L. var. *durum* Desf.	Grain yield	5.9	3.8	T	Francois et al., 1986
		Grasses and forage crops				
Alfalfa	*Medicago sativa* L.	Shoot DW	2.0	7.3	MS	Bernstein & Francois, 1973a; Bernstein & Ogata, 1966; Bower et al., 1969; Brown & Hayward, 1956; Gauch & Magistad, 1943; Hoffman et al., 1975
Alkaligrass, Nuttall	*Puccinellia airoides* (Nutt.) Wats. & Coult.	Shoot DW	—	—	T*	USSL staff, 1954
Alkali sacaton	*Sporobolus airoides* Torr.	Shoot DW	—	—	T*	USSL staff, 1954
Barley (forage)[†††]	*Hordeum vulgare* L.	Shoot DW	6.0	7.1	MT	Dregne, 1962; Hassan et al., 1970a
Bentgrass, creeping	*Agrostis stolonifera* L.	Shoot DW	—	—	MS	Younger et al., 1967
Bermudagrass[§§§]	*Cynodon dactylon* L. Pers.	Shoot DW	6.9	6.4	T	Bernstein & Ford, 1959b (p. 39–44); Bernstein & Francois, 1962 (p. 37–38); Langdale & Thomas, 1971
Bluestem, Angleton	*Dichanthium aristatum* (Poir.) C. E. Hubb. [syn. *Andropogon nodosus* (Willem.) Nash]	Shoot DW	—	—	MS*	Gausman et al., 1954
Broadbean	*Vicia faba* L.	Shoot DW	1.6	9.6	MS	Ayers & Eberhard, 1960
Brome, mountain	*Bromus marginatus* Nees ex Steud.	Shoot DW	—	—	MT*	USSL staff, 1954
Brome, smooth	*B. inermis* Leyss	Shoot DW	—	—	MT	McElgunn & Lawrence, 1973
Buffelgrass	*Pennisetum ciliare* (L.) Link. [syn. *Cenchrus ciliaris*]	Shoot DW	—	—	MS*	Gausman et al., 1954

Table 3–1. Continued.

Crop		Salt tolerance parameters				
Common name	Botanical name‡	Tolerance based on	Threshold¶ (EC_e)	Slope	Rating#	References
			dS/m	% per dS/m		
Burnet	*Poterium sanguisorba* L.	Shoot DW	—	—	MS*	USSL staff, 1954
Canarygrass, reed	*Phalaris arundinacea* L.	Shoot DW	—	—	MT	McElgunn & Lawrence, 1973
Clover, alsike	*Trifolium hybridum* L.	Shoot DW	1.5	12	MS	Ayers, 1948a
Clover, Berseem	*T. alexandrinum* L.	Shoot DW	1.5	5.7	MS	Asghar et al., 1962; Ayers & Eberhard, 1958 (p. 36–37); Ravikovitch & Porath, 1967; Ravikovitch & Yoles, 1971
Clover, Hubam	*Melilotus alba* Dest. var. *annua* H. S. Coe	Shoot DW	—	—	MT*	USSL staff, 1954
Clover, ladino	*Trifolium repens* L.	Shoot DW	1.5	12	MS	Ayers, 1948a; Gauch & Magistad, 1943
Clover, Persian	*T. resupinatum* L.	Shoot DW	—	—	MS*	de Forges, 1970
Clover, red	*T. pratense* L.	Shoot DW	1.5	12	MS	Ayers, 1948a; Saini, 1972
Clover, strawberry	*T. fragiferum* L.	Shoot DW	1.5	12	MS	Ayers, 1948a; Bernstein & Ford, 1959b (p. 39–44); Gauch & Magistad, 1943
Clover, sweet	*Melilotus sp.* Mill.	Shoot DW	—	—	MT*	USSL staff, 1954
Clover, white Dutch	*Trifolium repens* L.	Shoot DW	—	—	MS*	USSL staff, 1954
Corn (forage)§§	*Zea mays* L.	Shoot DW	1.8	7.4	MS	Hassan et al., 1970b; Ravikovitch, 1973; Ravikovitch & Porath, 1967
Cowpea (forage)	*Vigna unguiculata* (L.) Walp.	Shoot DW	2.5	11	MS	West & Francois, 1982

Table 3–1. Continued.

Dallisgrass	*Paspalum dilatatum* Poir.	Shoot DW	—	—	MS*	Russell, 1976
Dhaincha	*Sesbania bispinosa* (Linn.) W. F. Wight [syn. *Sesbania aculeata* (Willd.) Poir]	Shoot DW	—	—	MT	Girdhar, 1987; Karadge & Chavan, 1983
Fescue, tall	*Festuca elatior* L.	Shoot DW	3.9	5.3	MT	Bower et al., 1970; Brown & Bernstein, 1953 (p. 44–46)
Fescue, meadow	*Festuca pratensis* Huds.	Shoot DW	—	—	MT*	USSL staff, 1954
Foxtail, meadow	*Alopecurus pratensis* L.	Shoot DW	1.5	9.6	MS	Brown & Bernstein, 1953 (p. 44–46)
Glycine	*Neonotonia wightii* [syn. *Glycine wightii* or *javanica*]	Shoot DW	—	—	MS	Russell, 1976; Wilson, 1985
Gram, black or Urd bean	*Vigna mungo* (L.) Hepper [syn. *Phaseolus mungo* L.]	Shoot DW	—	—	S	Keating & Fisher, 1985
Grama, blue	*Bouteloua gracilis* (HBK) Lag. Ex Steud.	Shoot DW	—	—	MS*	USSL staff, 1954
Guinea grass	*Panicum maximum* Jacq.	Shoot DW	—	—	MT	Russell, 1976
Hardinggrass	*Phalaris tuberosa* L. var. *stenoptera* (Hack) A. S. Hitchc.	Shoot DW	4.6	7.6	MT	Brown & Bernstein, 1953 (p. 44–46)
Kallargrass	*Leptochloa fusca* (L.) Kunth [syn. *Diplachne fusca* Beauv.]	Shoot DW	—	—	T	Sandhu et al., 1981
Lablab bean	*Lablab purpureus* (L.) Sweet [syn. *Dolichos lablab* L.]	Shoot DW	—	—	MS	Russell, 1976
Lovegrass¶¶¶	*Eragrostis sp.* N. M. Wolf	Shoot DW	2.0	8.4	MS	Bernstein & Ford, 1959b (p. 39–44)
Milkvetch, Cicer	*Astragalus cicer* L.	Shoot DW	—	—	MS*	USSL staff, 1954
Millet, Foxtail	*Setaria italica* (L.) Beauvois	Dry matter	—	—	MS	Ravikovitch & Porath, 1967

Table 3–1. Continued.

Crop		Tolerance[§] based on	Salt tolerance parameters			References
Common name	Botanical name[‡]		Threshold[¶] (EC_e)	Slope	Rating[#]	
			dS/m	% per dS/m		
Oatgrass, tall	*Arrhenatherum elatius* (L.) Beauvois ex J. Presl & K. Presl	Shoot DW	—	—	MS*	USSL staff, 1954
Oat (forage)	*Avena sativa* L.	Straw DW	—	—	T	Mishra & Shitole, 1986; USSL[‡‡]
Orchardgrass	*Dactylis glomerata* L.	Shoot DW	1.5	6.2	MS	Brown & Bernstein, 1953 (p. 44–46); Wadleigh et al., 1951
Panicgrass, blue	*Panicum antidotale* Retz.	Shoot DW	—	—	MS*	Abd El-Rahman et al., 1972; Gausman et al., 1954
Pigeon pea	*Cajanus cajan* (L.) Huth [syn. *C. indicus* (K.) Spreng.]	Shoot DW	—	—	S	Subbaro et al., 1991; Keating & Fisher, 1985
Rape (forage)	*Brassica napus* L.		—	—	MT*	USSL staff, 1954
Rescuegrass	*Bromus unioloides* HBK	Shoot DW	—	—	MT*	USSL staff, 1954
Rhodesgrass	*Chloris Gayana* Kunth.	Shoot DW	—	—	MT	Abd El-Rahman et al., 1972; Gausman et al., 1954
Rye (forage)	*Secale cereale* L.	Shoot DW	7.6	4.9	T	Francois et al., 1989
Ryegrass, Italian	*Lolium multiforum* Lam.	Shoot DW	—	—	MT*	Shimose 1973
Ryegrass, perennial	*Lolium perenne* L.	Shoot DW	5.6	7.6	MT	Brown & Bernstein, 1953 (p. 44–46)
Ryegrass, Wimmera	*L. Rigidum* Gaud.		—	—	MT*	Malcolm & Smith, 1971
Saltgrass, desert	*Distichlis spicta* L. var. *stricta* (Torr.) Bettle	Shoot DW	—	—	T*	USSL staff, 1954
Sesbania	*Sesbania exaltata* (Raf.) V. L. Cory	Shoot DW	2.3	7.0	MS	Bernstein, 1956 (p. 33–34)

Table 3–1. Continued.

Sirato	*Macroptilium atropurpureum* (DC.) Urb.	Shoot DW	—	—	MS	Russell, 1976
Sphaerophysa	*Sphaerophysa salsula* (Pall.) DC	Shoot DW	2.2	7.0	MS	Francois & Bernstein, 1964a (p. 52–53)
Sudangrass	*Sorghum sudanense* (Piper) Stapf	Shoot DW	2.8	4.3	MT	Bower et al., 1970
Timothy	*Phleum pratense* L.	Shoot DW	—	—	MS*	Saini, 1972
Trefoil, big	*Lotus pedunculatus* Cav.	Shoot DW	2.3	19	MS	Ayers, 1948a,b (p. 23–25)
Trefoil, narrowleaf birdsfoot	*L. corniculatus* var *tenuifolium* L.	Shoot DW	5.0	10	MT	Ayers, 1948a,b (p. 23–25)
Trefoil, broadleaf birdsfoot	*L. corniculatus L.* var *arvenis* (Schkuhr) Ser. ex DC	Shoot DW	—	—	MS	Ayers, 1950b (p. 44–45)
Vetch, common	*Vicia angustifolia* L.	Shoot DW	3.0	11	MS	Ravikovitch & Porath, 1967
Wheat (forage)‡‡‡	*Triticum aestivum* L.	Shoot DW	4.5	2.6	MT	Francois et al., 1986
Wheat, Durum (forage)	*T. turgidum* L. var *durum* Desf.	Shoot DW	2.1	2.5	MT	Francois et al., 1986
Wheatgrass, standard crested	*Agropyron sibiricum* (Willd.) Beauvois	Shoot DW	3.5	4.0	MT	Bernstein & Ford, 1958 (p. 32–36)
Wheatgrass, fairway crested	*A. cristatum* (L.) Gaertn.	Shoot DW	7.5	6.9	T	Bernstein & Ford, 1958 (p. 32–36)
Wheatgrass, intermediate	*A. intermedium* (Host) Beauvois	Shoot DW	—	—	MT*	Dewey, 1960
Wheatgrass, slender	*A. trachycaulum* (Link) Malte	Shoot DW	—	—	MT	McElgunn & Lawrence, 1973
Wheatgrass, tall	*A. elongatum* (Hort) Beauvois	Shoot DW	7.5	4.2	T	Bernstein & Ford, 1958 (p. 32–36)
Wheatgrass, western	*A. Smithii* Rydb.	Shoot DW	—	—	MT*	USSL staff, 1954
Wildrye, Altai	*Elymus angustus* Trin.	Shoot DW	—	—	T	McElgunn & Lawrence, 1973
Wildrye, beardless	*E. triticoides* Buckl.	Shoot DW	2.7	6.0	MT	Brown & Bernstein, 1953

Table 3–1. Continued.

Crop		Tolerance[§] based on	Salt tolerance parameters			References
Common name	Botanical name[‡]		Threshold[¶] (EC_e)	Slope	Rating[#]	
			dS/m	% per dS/m		
Wildrye, Canadian	*E. canadensis* L.	Shoot DW	—	—	MT*	USSL staff, 1954
Wildrye, Russian	*E. junceus* Fisch.	Shoot DW	—	—	T	McElgunn & Lawrence, 1973
		Vegetables and fruit crops				
Artichoke	*Cynara scolymus* L.	Bud yield	6.1	11.5	MT	Francois, 1995
Asparagus	*Asparagus officinalis* L.	Spear yield	4.1	2.0	T	Francois, 1987
Bean, common	*Phaseolus vulgaris* L.	Seed yield	1.0	19	S	Bernstein & Ayers, 1951; Hoffman & Rawlins, 1970; Magistad et al., 1943; Nieman & Bernstein, 1959; Osawa, 1965
Bean, lima	*P. lunatus* L.	Seed yield	—	—	MT*	Mahmoud et al., 1988
Bean, mung	*Vigna radiata* (L.) R. Wilcz.	Seed yield	1.8	20.7	S	Minhas et al., 1990
Cassava	*Manihot esculenta* Crantz	Tuber yield	—	—	MS	Anonymous,1976; Hawker & Smith, 1982
Beet, red[†††]	*Beta vulgaris* L.	Storage root	4.0	9.0	MT	Bernstein et al., 1974; Hoffman & Rawlins, 1971; Magistad et al., 1943
Broccoli	*Brassica oleracea* L. (Botrytis Group)	Shoot FW	2.8	9.2	MS	Bernstein & Ayers, 1949a (p. 39); Bernstein et al., 1974
Brussel Sprout	*B. oleracea L.* (Gemmifera Group)		—	—	MS*	
Cabbage	*B. oleracea L.* (Capitata Group)	Head FW	1.8	9.7	MS	Bernstein & Ayers, 1949a (p. 39); Bernstein et al., 1974; Osawa, 1965

Table 3–1. Continued.

Carrot	*Daucus carota* L.	Storage root	1.0	14	S	Bernstein & Ayers, 1953a; Bernstein et al., 1974; Lagerwerff & Holland, 1960; Magistad et al., 1943; Osawa, 1965
Cauliflower	*Brassica oleracea* L. (Botrytis Group)		—	—	MS*	
Celery	*Apium graveolens* L. var dulce (Mill.) Pers.	Petiole FW	1.8	6.2	MS	Francois & West, 1982
Corn, sweet	*Zea mays* L.	Ear FW	1.7	12	MS	Bernstein & Ayers, 1949b (p. 41–42)
Cowpea	*Vigna unguiculata* (L.) Walp.	Seed yield	4.9	12	MT	West & Francois, 1982
Cucumber	*Cucumis sativus* L.	Fruit yield	2.5	13	MS	Osawa, 1965; Ploegman & Bierhuizen, 1970
Eggplant	*Solanum melongena* L. var *esculentum* Nees.	Fruit yield	1.1	6.9	MS	Heuer et al., 1986
Garlic	*Allium sativum* L.	Bulb yield	3.9	14.3	MS	Francois, 1994b
Gram, black or Urd bean	*Vigna mungo* (L.) Hepper [syn. *Phaseolus mungo* L.]	Shoot DW	—	—	S	Keating & Fisher, 1985
Kale	*Brassica oleracea* L. (Acephala Group)		—	—	MS*	Malcolm & Smith, 1971
Kohlrabi	*Brassica oleracea* L. (Gongylodes Group)		—	—	MS*	
Lettuce	*Lactuca sativa* L.	Top FW	1.3	13	MS	Ayers et al., 1951; Bernstein et al., 1974; Osawa, 1965
Muskmelon	*Cucumis melo* L. (Reticulatus Group)	Fruit yield	1.0	8.4	MS	Mangal et al., 1988; Shannon & Francois, 1978
Okra	*Abelmoschus esculentus* (L.) Moench	Pod yield	—	—	MS	Masih et al., 1978; Paliwal & Maliwal, 1972

Table 3–1. Continued.

Crop		Tolerance[§] based on	Salt tolerance parameters			References
Common name	Botanical name[‡]		Threshold[¶] (EC_e)	Slope	Rating[#]	
			dS/m	% per dS/m		
Onion (bulb)	*Allium cepa* L.	Bulb yield	1.2	16	S	Bernstein & Ayers, 1953b; Bernstein et al., 1974; Hoffman & Rawlins, 1971; Osawa, 1965
Onion (seed)	*Allium cepa* L.	Seed yield	1.0	8.0	MS	Mangal et al., 1989
Parsnip	*Pastinaca sativa* L.		—	—	S*	Malcolm & Smith, 1971
Pea	*Pisum sativum* L.	Seed FW	3.4	10.6	MS	Cerda et al., 1982
Pepper	*Capsicum annuum* L.	Fruit yield	1.5	14	MS	Bernstein, 1954 (p. 36–37); Osawa, 1965; USSL[‡‡]
Pigeon pea	*Cajanus cajan* (L.) Huth [syn. *C. indicus* (K.) Spreng.]	Shoot DW	—	—	S	Keating & Fisher, 1985; Subbarao et al., 1991
Potato	*Solanum tuberosum* L.	Tuber yield	1.7	12	MS	Bernstein et al., 1951
Pumpkin	*Cucurbita pepo* L. var *Pepo*		—	—	MS*	
Purslane	*Portulaca oleracea* L.	Shoot FW	6.3	9.6	MT	Kumamoto et al., 1992
Radish	*Raphanus sativus* L.	Storage root	1.2	13	MS	Hoffman & Rawlins, 1971; Osawa, 1965
Spinach	*Spinacia oleracea* L.	Top FW	2.0	7.6	MS	Langdale et al., 1971; Osawa, 1965
Squash, scallop	*Cucurbita pepo* L. var *melopepo* L. Alef.	Fruit yield	3.2	16	MS	Francois, 1985
Squash, zucchini	*C. pepo* L. var *melopepo* (L.) Alef.	Fruid yield	4.9	10.5	MT	Francois, 1985; Graifenberg et al., 1996
Strawberry	*Fragaria x ananassa* Duch.	Fruit yield	1.0	33	S	Ehlig & Bernstein, 1958; Osawa, 1965
Sweet potato	*Ipomoea batatas* (L.) Lam.	Fleshy root	1.5	11	MS	Greig & Smith, 1962; USSL[‡‡]

Table 3–1. Continued.

Tepary bean	*Phaseolus acutifolius* Gray		—	—	MS*	Goertz & Coons, 1991; Hendry, 1918; Perez & Minguez, 1985
Tomato	*Lycopersicon lycopersicum* (L.) Karst. Ex Farw. [syn. *Lycopersicon esculentum* Mill.]	Fruit yield	2.5	9.9	MS	Bierhuizen & Ploegman, 1967; Hayward & Long, 1943; Lyon, 1941; Shalhevet & Yaron, 1973
Tomato, cherry	*L. lycopersicum* var. *Cerasiforme* (Dunal) Alef.	Fruit yield	1.7	9.1	MS	Caro et al., 1991
Turnip	*Brassica rapa* L. (Rapifera Group)	Storage root	0.9	9.0	MS	Francois, 1984a
Turnip (greens)		Top FW	3.3	4.3	MT	Francois, 1984a
Watermelon	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	Fruit yield	—	—	MS*	de Forges, 1970
Winged bean	*Psophocarpus tetragonolobus* L. DC	Shoot DW	—	—	MT	Weil & Khalil, 1986

† These data serve only as a guideline to relative tolerances among crops. Absolute tolerances vary, depending upon climate, soil conditions, and cultural practices.

‡ Botanical and common names follow the convention of Hortus Third (Liberty Hyde Bailey Hortorium Staff, 1976) where possible.

§ FW = fresh weight, DW = dry weight.

¶ In gypsiferous soils, plants will tolerate EC_e's about 2 dS/m higher than indicated.

Ratings are defined by the boundaries in Fig. 3–3. (Ratings with an * are estimates.)

†† Less tolerant during seedling stage, EC_e at this stage should not exceed 4 or 5 dS/m.

‡‡ Unpublished U.S. Salinity Laboratory data.

§§ Grain and forage yields of DeKalb XL-75 grown on an organic muck soil decreased about 26% per deciSiemen/meter above a threshold of 1.9 dS/m (Hoffman et al., 1983).

¶¶ Because paddy rice is grown under flooded conditions, values refer to the electrical conductivity of the soil water while the plants are submerged. Less tolerant during seedling stage.

Sesame cultivars, Sesaco 7 and 8, may be more tolerant than indicated by the S rating.

††† Sensitive during germination and emergence, EC_e should not exceed 3 dS/m.

‡‡‡ Data from one cultivar, Probred.

§§§ Average of several varieties. Suwannee and Coastal are about 20% more tolerant, and common and Greenfield are about 20% less tolerant than the average.

¶¶¶ Average for Boer, Wilman, Sand, and Weeping cultivars (Lehmann seems about 50% more tolerant).

The data in Table 3–1 apply to soils where Cl^- is the predominant anion. Because of the dissolution of $CaSO_4$ when preparing saturated-soil extracts, the EC_e of gypsiferous (nonsodic, low Mg^{2+}) soils will range from 1 to 3 dS m^{-1} higher than that of nongypsiferous soils having the same soil water conductivity at field capacity (Bernstein, 1962). The extent of this dissolution depends upon the exchangeable ion composition, cation exchange capacity, and solution composition. Therefore, plants grown on gypsiferous soils will tolerate EC_e's approximately 2 dS m^{-1} higher than those listed in Table 3–1. The last column provides a qualitative salt tolerance rating that is useful in categorizing crops in general terms. The limits of these categories are illustrated in Fig. 3–3. Some crops are listed with only a qualitative rating because experimental data are inadequate to calculate the threshold and slope.

B. Woody Crops

The salt tolerance of trees, vines, and other woody crops is complicated because of additional detrimental effects caused by specific ion toxicities. Many perennial woody species are susceptible to foliar injury caused by the toxic accumulation of Cl^- and/or Na^+ in the leaves. Because different cultivars and rootstocks absorb Cl^- and Na^+ at different rates, considerable variation in tolerance may occur within an individual species. Tolerances to these specific ions are discussed below.

In the absence of specific-ion effects, the tolerance of woody crops, like that of herbaceous crops, can be expressed as a function of the concentration of total soluble salts or osmotic potential of the soil solution. One could expect this condition to obtain for those cultivars and rootstocks that restrict the uptake of Cl^- and Na^+. The salt tolerance data given in Table 3–2 for woody crops are believed to be reasonably accurate in the absence of specific-ion toxicities.

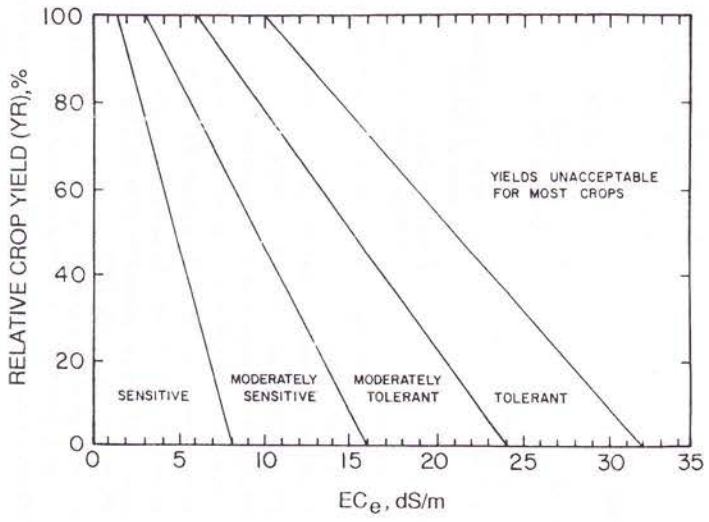

Fig. 3–3. Divisions for classifying crop tolerance to salinity.

Table 3–2. Salt tolerance of woody crops.†

Crop		Tolerance based on:	Salt tolerance parameters			References
Common name	Botanical name‡		Threshold§ (EC_e)	Slope	Rating¶	
			dS/m	% per dS/m		
Almond	*Prunus duclis* (Mill.) D.A. Webb	Shoot growth	1.5	19	S	Bernstein et al., 1956; Brown et al., 1953
Apple	*Malus sylvestris* Mill.		—	—	S	Ivanov, 1970
Apricot	*Prunus armeniaca* L.	Shoot growth	1.6	24	S	Bernstein et al., 1956
Avocado	*Persea americana* Mill.	Shoot growth	—	—	S	Ayers, 1950a; Haas, 1950
Banana	*Musa acuminata* Colla	Fruit yield	—	—	S	Israeli et al., 1986
Blackberry	*Rubus macropetalus* Doug. ex Hook	Fruit yield	1.5	22	S	Ehlig, 1964
Boysenberry	*Rubus ursinus* Cham. and Schlechtend	Fruit yield	1.5	22	S	Ehlig, 1964
Castorbean	*Ricinus communis* L.		—	—	MS*	USSL staff, 1954
Cherimoya	*Annona cherimola* Mill.	Foliar injury	—	—	S	Cooper et al., 1952
Cherry, sweet	*Prunus avium* L.	Foliar injury	—	—	S*	Beeftink, 1955
Cherry, sand	*Prunus besseyi* L., H. Baley	Foliar injury, stem growth	—	—	S*	Zhemchuzhnikov, 1946
Coconut	*Cocos nucifera* L.		—	—	MT*	Kulkarni et al., 1973
Currant	*Ribes sp.* L.	Foliar injury, stem growth	—	—	S*	Beeftink, 1955; Zhemchuzhnikov, 1946
Date palm	*Phoenix dactylifera* L.	Fruit yield	4.0	3.6	T	Furr & Armstrong, 1962; (p. 11–13); Furr & Ream, 1968; Furr et al., 1966
Fig	*Ficus carica* L.	Plant DW	—	—	MT*	Patil & Patil, 1983a; USSL staff, 1954
Gooseberry	*Ribes sp.* L.		—	—	S*	Beeftink, 1955
Grape	*Vitus vinifera* L.	Shoot growth	1.5	9.6	MS	Groot Obbink & Alexander, 1973; Nauriyal & Gupta, 1967; Taha et al., 1972

Table 3–2. Continued.

Crop		Tolerance based on:	Salt tolerance parameters			References
Common name	Botanical name[‡]		Threshold[§] (EC_e)	Slope	Rating[¶]	
			dS/m	% per dS/m		
Grapefruit	*Citrus x paradisi* Macfady.	Fruit yield	1.2	13.5	S	Bielorai et al., 1978
Guava	*Psidium guajava* L.	Shoot & root growth	4.7	9.8	MT	Patil et al., 1984
Guayule	*Parthenium argentatum* A. Gray	Shoot DW rubber yield	8.7 7.8	11.6 10.8	T T	Maas et al., 1988
Jambolan plum	*Syzygium cumini* L.	Shoot growth	—	—	MT	Patil & Patil, 1983b
Jojoba	*Simmondsia chinensis* (Link) C. K. Schneid	Shoot growth	—	—	T	Tal et al., 1979; Yermanos et al., 1967
Jujube, Indian	*Ziziphus mauritiana* Lam.	Fruit yield	—	—	MT	Hooda et al., 1990
Lemon	*Citrus limon* (L.) Burm. F.	Fruit yield	1.5	12.8	S	Cerda et al., 1990
Lime	*Citrus aurantiifolia* (Christm.) Swingle		—	—	S*	
Loquat	*Eriobotrya japonica* (Thunb.) Lindl.	Foliar injury	—	—	S*	Cooper & Link, 1953; Malcolm & Smith, 1971
Macadamia	*Macadamia integrifolia* Maiden & Betche	Seedling growth	—	—	MS*	Hue & McCall, 1989
Mandarin orange; tangerine	*Citrus reticulata* Blanco	Shoot growth	—	—	S*	Minessy et al., 1974
Mango	*Mangifera indica* L.	Foliar injury	—	—	S	Cooper et al., 1952
Natal plum	*Carissa grandiflora* (E. H. Mey.) A. DC.	Shoot growth	—	—	T	Bernstein et al., 1972
Olive	*Olea europaea* L.	Seedling growth, fruit yield	—	—	MT	Bidner-Barhava & Ramati, 1967; Taha et al., 1972
Orange	*Citrus sinensis* (L.) Osbeck	Fruit yield	1.3	13.1	S	Bielorai et al., 1988; Bingham et al., 1974; Dasberg et al., 1991; Harding et al., 1958
Papaya	*Carica papaya* L.	Seedling growth, foliar injury	—	—	MS	Kottenmeier et al., 1983; Makhija & Jindal, 1983

Table 3–2. Continued.

Passion fruit	*Passiflora edulis* Sims.		—	—	S*	Malcolm & Smith, 1971
Peach	*Prunus persica* (L.) Batsch	Shoot growth, fruit yield	1.7	21	S	Bernstein et al., 1956; Brown, et al., 1953; Hayward et al., 1946
Pear	*Pyrus communis* L.		—	—	S*	USSL staff, 1954
Pecan	*Carya illinoinensis* (Wangeth) C. Koch	Nut yield, trunk growth	—	—	MS	Miyamoto et al., 1986
Persimmon	*Diospyros virginiana* L.		—	—	S*	Malcolm & Smith, 1971
Pineapple	*Ananas comosus* (L.) Merrill	Shoot DW	—	—	MT	Wambiji & El-Swaify, 1974
Pistachio	*Pistacia vera* L.	Shoot growth	—	—	MS	Sepaskhah & Maftoun, 1988; Picchioni et al., 1990
Plum; prune	*Prunus domestica* L.	Fruit yield	2.6	31	MS	Hoffman et al., 1989
Pomegranate	*Punica granatum* L.	Shoot growth	—	—	MS	Patil & Patil, 1982
Popinac, white	*Leucaena leucocephala* (Lam.) De Wit [syn. *Leucaena glauca* Benth.]	Shoot DW	—	—	MS	Gorham et al., 1988; Hansen & Munns, 1988
Pummelo	*Citrus maxima* (Burm.)	Foliar injury	—	—	S*	Furr & Ream, 1969
Raspberry	*Rubus idaeus* L.	Fruit yield	—	—	S	Ehlig, 1964
Rose apple	*Syzygium jambos* (L.) Alston	Foliar injury	—	—	S*	Cooper & Gorton, 1951 (p. 32–38)
Sapote, white	*Casimiroa edulis* Llave	Foliar injury	—	—	S*	Cooper et al., 1952
Scarlet wisteria	*Sesbania grandiflora*	Shoot DW	—	—	MT	Chavan & Karadge, 1986
Tamarugo	*Prosopis tamarugo* Phil.	Observation	—	—	T	Natl. Acad. Sci., 1975
Walnut	*Juglans* spp.	Foliar injury	—	—	S*	Beeftink, 1955

† These data serve only as a guideline to relative tolerances among crops. Absolute tolerances vary, depending upon climate, soil conditions, and cultural practices. The data are applicable when rootstocks are used that do not accumulate Na^+ or Cl^- rapidly or when these ions do not predominate in the soil.

‡ Botanical and common names follow the convention of Hortus Third (Liberty Hyde Bailey Hortorium Staff, 1976) where possible.

§ In gypsiferous soils, plants will tolerate EC_e's about 2 dS/m higher than indicated.

¶ Ratings are defined by the boundaries in Fig. 3–3. Ratings with an * are estimates.

Because of the cost and time required to obtain fruit yields, tolerances of several crops have been determined for vegetative growth only. In contrast to other crop groups, most woody fruit and nut crops tend to be salt sensitive, even in the absence of specific-ion effects. Only date palm is relatively salt tolerant, whereas olive and a few others are believed to be moderately tolerant.

VII. PLANT TOLERANCE TO SALINE SPRINKLING WATERS

Sprinkler-irrigated crops are subject to additional salt damage when the foliage is wetted by saline water. Salts are directly accumulated by the leaves and as a result, some species become severely injured and lose their leaves. Of course, sprinkler-irrigated crops are subject to injury from both soil salinity and salt spray. Any genetically controlled mechanisms that may have evolved in plants to restrict Na^+ and Cl^- from the shoot may become irrelevant under sprinkler irrigation. The degree of injury is related to the salt concentration in the leaves but weather conditions and water stress can influence the onset of injury. For instance, leaves may contain toxic levels of Na^+ or Cl^- for several weeks without exhibiting any injury symptoms, but the first hot, dry weather will cause severe leaf necrosis. Consequently, there are no practical guidelines for correlating foliar injury to salt concentrations of the leaves.

A. Salt Tolerance of Sprinkled Crops

Since crops sprinkled with saline water also are exposed to soil salinity, yield reductions caused by saline irrigation waters will be at least as great as they are for surface-irrigated crops. Additional yield reduction can be expected for those crops that are susceptible to foliar damage caused by salts absorbed directly through the leaves. Bernstein and Francois (1973b) found that pepper yields were decreased 16% when furrow irrigated with 4.5 dS m^{-1} water as compared with 0.6 dS m^{-1} water; but were decreased 54% when irrigated by sprinkler. A later study indicated that yields of sprinkler-irrigated peppers were reduced about 16% for each 1 dS m^{-1} increase in the EC of the water (Bernstein & Francois, 1975). Sprinkling daily with 3.1 dS m^{-1} water caused similar reductions in yield of peppers in Israel (Goldberg & Shmueli, 1971). Tomatoes sprinkled with 3.6 dS m^{-1} water produced only 38% as much fruit as plants that were drip irrigated with the same water (Gornat et al., 1973). Even cotton, which is one of the most salt-tolerant crops, produced significantly less (15%) seed cotton when sprinkled during the day than when surface irrigated with 4.4 dS m^{-1} water (Busch & Turner, 1967). It is worth noting that sprinkling at night did not decrease yields of cotton.

Except for the pepper data above, no data are available yet to predict yield losses as a function of salt concentration in sprinkler irrigation water. However, limited data for some crops allow estimates of threshold EC of the irrigation water (EC_i) based on sprinkling-induced foliar injury (Table 3–3). These thresholds are compared with EC_i thresholds based on yield reductions attributed to soil salinity. Those crops that have foliar injury thresholds below the soil salinity threshold have a high likelihood of foliar injury when sprinkled with waters that

Table 3–3. Relative susceptibility of crops to foliar injury from saline sprinkling waters.[†]

Na or Cl concentration causing foliar injury[‡] (mol m^{-3})			
<5	5–10	10–20	>20
Almond	Grape	Alfalfa	Cauliflower
Apricot	Pepper	Barley	Cotton
Citrus	Potato	Corn	Sugar Beet
Plum	Tomato	Cucumber	Sunflower
		Safflower	
		Sesame	
		Sorghum	

[†] Susceptibility based on direct accumulation of salts through the leaves. Data compiled from Ehlig and Bernstein (1959), Francois and Clark (1979), Gornat et al. (1973), Maas et al. (1982a), and Maas et al. (1982b).

[‡] Foliar injury is influenced by cultural and environmental conditions. These data are presented only as general guidelines for daytime sprinkling.

have salt concentrations equal to or above the soil salinity threshold. At concentrations above both thresholds, both foliar injury and yield reductions can be expected. If the effects are additive, yield losses greater than those indicated in Table 3–1 are likely to occur. One method that may provide a way to obtain salinity-production functions for sprinkler-irrigated crops may be the triple-line-source sprinkler method (Aragüés et al., 1992).

Obviously, saline irrigation water is best distributed through surface distribution systems. However, if sprinkling with marginally saline water cannot be avoided, several precautions should be considered. If possible, susceptible crops should be irrigated below the plant canopy to eliminate or reduce wetting of the foilage. Since injury is related more to the number of sprinklings than to their duration, infrequent, heavy irrigations would be preferable to frequent, light irrigations. Intermittent wetting by slowly rotating sprinklers that allow drying between cycles should be avoided. Lateral-move sprinkler systems might be moved downwind, when possible, so that salts accumulated on the leaves from salt drift would be washed off as the sprinkler moves past. Perhaps the best strategy to minimize foliar injury to plants is to irrigate at night when both evaporation and salt absorption are reduced. If daytime sprinkling is necessary, hot, dry, windy days should be avoided.

Recent work has shown that sprinkling with low-salinity water for 3 to 5 min either prior to or after sprinkler irrigations with saline water effectively reduced foliar-salt accumulation and injury in barley and corn (Aragüés et al., 1994; Benes et al., 1996). They concluded that much of the salt accumulated by wetted leaves is absorbed during the first few minutes of irrigation and also after sprinkling while the saline water evaporates and concentrates on the leaf surface. Sprinkling barley with 9.6 dS m^{-1} water reduced grain yields by 58% compared to unsprinkled plants, but when saline sprinkled plants received both pre-and postwashing with nonsaline water, yields were reduced only 17% (Benes et al., 1996). The soil surface was covered to shed the sprinkling

waters in all cases. This information may be useful to growers who have access to and can readily switch between sources of irrigation waters of different quality.

VIII. CROP RESPONSE TO SPECIFIC IONS AND ELEMENTS

As mentioned above, the relative concentrations of Na^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, and HCO_3^- vary over a wide range in saline soils and waters. But unless the ratios between these ions become extreme, most crops respond to the solutes in the soil solution as a function of its osmotic potential. Nevertheless, some herbaceous crops and many woody species are susceptible to direct ion toxicities or nutritional imbalances caused by these ions. These specific effects will be considered individually.

A. Sodium

Although Na^+ is not considered an essential element for most crop plants, it does have beneficial effects on the growth of some plants at concentrations below the salt tolerance threshold. At concentrations above the threshold, Na^+ can have both direct and indirect detrimental effects on plants. Direct effects are caused by the accumulation of toxic levels of Na^+ and are generally limited to woody species. Their ability to tolerate Na^+ varies considerably because Na^+ uptake varies widely among species and rootstocks. The Na^+ injury on avocado, citrus, and stone-fruit trees is rather widespread and can occur at Na^+ concentrations as low as 5 mol m^{-3} in soil water. The symptoms may not appear immediately after exposure to saline water, however. Initially, Na^+ is retained in the roots and lower trunk, but after 3 or 4 years the conversion of sapwood to heartwood apparently releases the accumulated Na^+ which is transported to the leaves causing leaf burn (Bernstein et al., 1956).

Indirect effects include both nutritional imbalance and impairment of soil physical conditions. The nutritional effects of Na^+ are not simply related to the exchangeable Na^+ percentage of soils but depend upon the concentrations of Na^+, Ca^{2+}, and Mg^{2+} in the soil solution. In sodic, nonsaline soils, total soluble salt concentrations are low and consequently, Ca^{2+} and/or Mg^{2+} concentrations are often nutritionally inadequate. These deficiencies and not Na^+ toxicity per se are usually the primary cause of poor plant growth among nonwoody species. Furthermore, since Na^+ uptake by plants is strongly regulated by Ca^{2+} in the soil solution, the presence of sufficient Ca^{2+} is essential to prevent the accumulation of toxic levels of Na^+. This is particularly important with Na^+-sensitive woody crops. As a general guide, Ca^{2+} and Mg^{2+} concentrations in the soil solution above 1 mol m^{-3} each, with $Ca^{2+} \geq Mg^{2+}$, are nutritionally adequate in nonsaline, sodic soils (Carter et al., 1979; Hanson, 1983).

As the total salt concentration increases into the saline-sodic range, Ca^{2+} concentrations become adequate for most plants and osmotic effects begin to predominate. However, some species are susceptible to salinity-induced Ca^{2+} deficiencies as indicated above.

Sodic soil conditions affect almost all crops because of the deterioration of soil-physical conditions. Dispersion of soil aggregates in sodic soils decreases soil permeability to water and air, thereby reducing plant growth. Poorly structured soils also result in prolonged saturated environments which encourage root disease. Therefore, yield reductions in crops that are not specifically sensitive to Na^+ reflect the combined effects of nutritional problems and all problems associated with impaired soil physical condition.

B. Chloride

Chlorine is an essential micronutrient for plants but unlike most micronutrients, it is relatively nontoxic (Maas, 1986). In fact, most nonwoody crops are not specifically sensitive to Cl^-. One exception to this generalization involves certain cultivars of soybean which tend to accumulate excessive and toxic amounts of Cl^- (Abel & McKenzie, 1964; Parker et al., 1983). Tolerant cultivars restrict Cl^- transport to the shoots. Many woody species also are susceptible to Cl^- toxicity which varies among varieties and rootstocks within species. As in soybean, these differences usually reflect the plant's ability to prevent or retard Cl^- translocation to the tops. Cooper (1951, p. 24–28, 1961) found that the salt tolerance of avocado, grapefruit, and orange is closely related to the Cl^- accumulation properties of the rootstocks. Similar effects of rootstocks on salt accumulation and tolerance have been reported for stone-fruit trees (Bernstein et al., 1956). Large differences in the salt tolerance of grape varieties have been linked with the Cl^--accumulating characteristics of different rootstocks (Bernstein et al., 1969; Ehlig, 1960; Groot Obink & Alexander, 1973; Sauer, 1968). By selecting rootstocks that exclude Cl^- from the scions, this problem can be avoided.

Table 3–4 lists for some fruit-crop cultivars and rootstocks the maximum Cl^- concentrations permissible in the soil water that do not cause leaf injury. In some cases, however, the osmotic threshold may be exceeded so that yield is decreased without obvious injury. The list is by no means complete since quantitative data for many cultivars and rootstocks are not available.

The major detrimental effect of Cl^- results from its contribution to the overall osmotic stress. No comprehensive testing has been done to specifically determine crop tolerances to Cl^- salinity but since most of the salt tolerance data were obtained in field plots salinized with chloride salts of Na^+ and Ca^{2+}, the data can be converted to express tolerances in terms of Cl^- concentration. If Cl^- is the predominant anion in the soil solution, then Cl^- concentration $[Cl^-]$, can be approximated from the electrical conductivity by Eq. [6]

$$[Cl^-] \approx 10 \times EC \qquad [6]$$

where $[Cl^-]$ is expressed in moles/cubic meter and EC in decisiemens/meter (U.S. Salin. Lab., 1954). Multiplying the threshold values in Tables 3–1 and 3–2 by 10 gives the maximum allowable Cl^- concentration in moles/cubic meter in the saturated-soil extract without a loss in yield. Dividing the slope by 10 gives the percentage yield decrease expected per each 1 mol m^{-3} increase in Cl^- concentration above the threshold.

Table 3–4. Chloride-tolerance limits of some fruit-crop rootstocks and cultivars.

Crop	Rootstock or cultivar	Maximum permissible Cl^- in soil water without leaf injury[†]
		(mol m^{-3})
Rootstocks		
Avocado	West Indian	15
(*Persea americana*)	Guatemalan	12
	Mexican	10
Citrus		
(*Citrus* sp.)	Sunki mandarin, grapefruit	50
	Cleopatra mandarin, Rangpur lime	50
	Sampson tangelo, rough lemon[‡]	30
	sour orange, Ponkan mandarin	30
	Citrumelo 4475, trifoliate orange	20
	Cuban shaddock	20
	Calamondin, sweet orange	20
	Savage citrange, Rusk citrange	20
	Troyer citrange	20
Grape		
(*Vitis* sp.)	Salt Creek, 1613–3	80
	Dog ridge	60
Stone fruit		
(*Prunus* sp.)	Marianna	50
	Lovell, Shalil	20
	Yunnan	15
Cultivars		
Berries[§]	Boysenberry	20
(*Rubus* sp.)	Olallie blackberry	20
	Indian Summer raspberry	10
Grape		
(*Vitis* sp.	Thompson seedless, Perlette	40
	Cardinal, black rose	20
Strawberry		
(*Fragaria* sp.)	Lassen	15
	Shasta	10

[†] For some crops, these concentrations may exceed the osmotic threshold and cause some yield reduction. [Data compiled from Bernstein (1965), Bernstein et al. (1969), and Embleton et al. (1962, 1973).]

[‡] Data from Australia indicates that rough lemon is more sensitive to Cl^- than sweet orange (Grieve & Walker, 1983).

[§] Data available for one variety of each species only.

C. Boron

Boron (B) is an essential element but, unlike Cl^-, it can become toxic to some plants when soil-water concentrations exceed only slightly that required for optimum plant growth. Generally, toxic concentrations in the soil are found only in arid regions of the world. Most surface irrigation waters contain acceptable B levels, but there are some areas where well waters contain toxic levels of B. Since plants vary in their tolerance to B, a water that is marginal for sensitive crops may be used for the more tolerant plants.

Much of the existing B tolerance data were obtained from experiments conducted during 1930 to 1934 by Eaton (1944). These data provided threshold tolerance limits for more than 40 different crops. While very useful, Eaton's experimental data can not be fitted to any reliable growth response function for most crops. Nevertheless, they are the source of most of the threshold tolerance limits presented in Table 3–5. More recent data have shown that plant response to excess B can be described by the two-piece linear response model (Bingham et al., 1985; Francois, 1984b, 1986, 1988, 1989, 1991, 1992). These data have provided threshold and slope parameters for a limited number of crops and are included in Table 3–5. With few exceptions, the B tolerance data are based on crop responses to different B levels in sand cultures. The thresholds indicate maximum permissible concentrations in the soil water that do not cause yield reductions. Some crops, however, may exhibit leaf injury at lower concentrations without decreasing yield. The crops have been classified in six groups, ranging from very sensitive to very tolerant. Like salt tolerance, B tolerance varies with climate, soil conditions, and crop cultivars; therefore the data may not apply to all cultural conditions. Different rootstocks of citrus and stone fruits absorb B at different rates so that tolerance may be improved by using rootstocks that restrict B uptake. A number of these rootstocks are listed in order of increasing boron accumulation in Table 3–6.

D. Bicarbonate

A few reports in the literature indicate that sensitivity to HCO_3^- differs among crop species. At 12 mol m^{-3}, HCO_3^- was highly toxic to Dallisgrass (*Paspalum dilatatum*) but had no effect on Rhodesgrass (*Chloris gayana*) (Gauch & Wadleigh, 1951). Bean plants are much more sensitive than beet plants (Brown & Wadleigh, 1955). Stolwijk and Thimann (1957) found that aerating the root medium with 6.5% CO_2 in air completely inhibited the root growth of bean, broad bean, pea, and sunflower but had no effect on that of oat and barley. Unfortunately, the data on HCO_3^- effects are so limited that plant tolerance limits for HCO_3^- concentrations in soils or irrigation waters remain unknown. Further work is clearly warranted in this area.

E. Selenium and Other Trace Elements

Since the publication of *Drainage for Agriculture* (Agron. Monogr. 17), environmental concerns related to trace elements have added a new dimension to drainage management and disposal. Certain irrigated soils derived from sedimentary rock materials contain or at least originally contained high concentrations of trace elements. Many of these elements are dissolved in the soil-water and move to the shallow ground water. Pratt and Suarez (1990) provide a table that lists the recommended maximum concentration of 15 trace elements in irrigation waters that provide for the long-term protection of plants and animals. However, the recent concern that these elements pose for irrigated agriculture is not so much their effects on limiting production, but rather the toxicological effects they can cause when drainage effluents that contain them are used for irrigation or discharged into bodies of water. If such effluents are used to supplement irrigation water supplies,

Table 3–5. Boron tolerance limits for agricultural crops.

Crop			Boron tolerance parameters			
Common Name	Botanical name	Tolerance based on:†	Threshold‡	Slope	Rating§	References
			g m^{-3}	% per g m^{-3}		
Alfalfa	*Medicago sativa* L.	Shoot DW	4.0–6.0		T	Eaton, 1944
Apricot	*Prunus armeniaca* L.	Leaf & stem injury	0.5–0.75		S	Woodbridge, 1955
Artichoke, globe	*Cynara scolymus* L.	Laminae DW	2.0–4.0		MT	Eaton, 1944
Artichoke, Jerusalem	*Helianthus tuberosus* L.	Whole plant DW	0.75–1.0		S	Eaton, 1944
Asparagus	*Asparagus officinalis* L.	Shoot DW	10.0–15.0		VT	Eaton, 1944
Avocado	*Persea americana* Mill.	Foliar injury	0.5–0.75		S	Haas, 1929
Barley	*Hordeum vulgare* L.	Grain yield	3.4	4.4	MT	Bingham et al., 1985
Bean, kidney	*Phaseolus vulgaris* L.	Whole plant DW	0.75–1.0		S	Eaton, 1944
Bean, lima	*Phaseolus lunatus* L.	Whole plant DW	0.75–1.0		S	Eaton, 1944
Bean, mung	*Vigna radiata* L. R.Wilcz.	Shoot length	0.75–1.0		S	Khudairi, 1961
Bean, snap	*Phaseolus vulgaris* L.	Pod yield	1.0	12	S	Francois, 1989
Beet, red	*Beta vulgaris* L.	Root DW	4.0–6.0		T	Eaton, 1944
Blackberry	*Rubus sp.* L.	Whole plant DW	<0.5		VS	Eaton, 1944
Bluegrass, Kentucky	*Poa pratensis* L.	Leaf DW	2.0–4.0		MT	Eaton, 1944
Broccoli	*Brassica oleracea* L. (Botrytis group).	Head FW	1.0	1.8	MS	Francois, 1986
Cabbage	*Brassica oleracea* L. (Capitata group)	Whole plant DW	2.0–4.0		MT	Eaton, 1944
Carrot	*Daucus carota* L.	Root DW	1.0–2.0		MS	Eaton, 1944
Cauliflower	*Brassica oleracea* L. (Botrytis group)	Curd FW	4.0	1.9	MT	Francois, 1986
Celery	*Apium graveolens* L. var. *dulce* (Mill.) Pers.	Petiole FW	9.8	3.2	VT	Francois, 1988
Cherry	*Prunus avium* L.	Whole plant DW	0.5–0.75		S	Eaton, 1944
Clover, sweet	*Melilotus indica* All.	Whole plant DW	2.0–4.0		MT	Eaton, 1944
Corn	*Zea mays* L.	Shoot DW	2.0–4.0		MT	El-Sheikh et al., 1971
Cotton	*Gossypium hirsutum* L.	Boll DW	6.0–10.0		VT	Eaton, 1944

Table 3–5. Continued.

Cowpea	*Vigna unguiculata* (L.) Walp.	Seed yield	2.5	12	MT	Francois, 1989
Cucumber	*Cucumis sativus* L.	Shoot DW	1.0–2.0		MS	El-Sheikh et al., 1971
Fig, kadota	*Ficus carica* L.	Whole plant DW	0.5–0.75		S	Eaton, 1944
Garlic	*Allium sativum* L.	Bulb yield	4.3	2.7	T	Francois, 1991
Grape	*Vitis vinifera* L.	Whole plant DW	0.5–0.75		S	Eaton, 1944
Grapefruit	*Citrus x paradisi* Macfady.	Foliar injury	0.5–0.75		S	Haas, 1929
Lemon	*Citrus limon* (L.) Burm. f.	Foliar injury, plant DW	<0.5		VS	Eaton, 1944; Haas, 1929
Lettuce	*Lactuca sativa* L.	Head FW	1.3	1.7	MS	Francois, 1988
Lupine	*Lupinus hartwegii* Lindl.	Whole plant DW	0.75–1.0		S	Eaton, 1944
Muskmelon	*Cucumis melo* L. (Reticulatus group)	Shoot DW	2.0–4.0		MT	Eaton, 1944,;El-Sheikh et al., 1971
Mustard	*Brassica juncea* Coss.	Whole plant DW	2.0–4.0		MT	Eaton, 1944
Oat	*Avena sativa* L.	Grain (immature) DW	2.0–4.0		MT	Eaton, 1944
Onion	*Allium cepa* L.	Bulb yield	8.9	1.9	VT	Francois, 1991
Orange	*Citrus sinensis* (L.) Osbeck	Foliar injury	0.5–0.75		S	Haas, 1929
Parsley	*Petroselinum crispum* Nym.	Whole plant DW	4.0–6.0		T	Eaton, 1944
Pea	*Pisum sativa* L.	Whole plant DW	1.0–2.0		MS	Eaton, 1944
Peach	*Prunus persica* (L.) Batsch.	Whole plant DW	0.5–0.75		S	Eaton, 1944; Haas, 1929
Peanut	*Arachis hypogaea* L.	Seed yield	0.75–1.0		S	Gopal, 1971
Pecan	*Carya illinoinensis* (Wangenh.) C. Koch	Foliar injury	0.5–0.75		S	Haas, 1929
Pepper, red	*Capsicum annuum* L.	Fruit yield	1.0–2.0		MS	Eaton, 1944
Persimmon	*Diospyros kaki* L.f.	Whole plant DW	0.5–0.75		S	Eaton, 1944
Plum	*Prunus domestica* L.	Leaf & stem injury	0.5–0.75		S	Woodbridge, 1955
Potato	*Solanum tuberosum* L.	Tuber DW	1.0–2.0		MS	Eaton, 1944
Radish	*Raphanus sativus* L.	Root FW	1.0	1.4	MS	Francois, 1986
Sesame	*Sesamum indicum* L.	Foliar injury	0.75–1.0		S	Khudairi, 1961

Table 3–5. Continued.

Crop			Boron tolerance parameters			
Common Name	Botanical name	Tolerance based on:	Threshold[‡]	Slope	Rating[§]	References
			g m^{-3}	% per g m^{-3}		
Sorghum	*Sorghum bicolor* (L.) Moench	Grain yield	7.4	4.7	VT	Bingham et al., 1985
Squash, scallop	*Cucurbita pepo* L. var *melopepo* (L.) Alef.	Fruit yield	4.9	9.8	T	Francois, 1992
Squash, winter	*Cucurbita moschata* Poir	Fruit yield	1.0	4.3	MS	Francois, 1992
Squash, zucchini	*Cucurbita pepo* L. var *melopepo* L. Alef.	Fruit yield	2.7	5.2	MT	Francois, 1992
Strawberry	*Fragaria sp.* L.	Whole plant DW	0.75–1.0		S	Eaton, 1944
Sugar beet	*Beta vulgaris* L.	Storage root FW	4.9	4.1	T	Vlamis & Ulrich, 1973
Sunflower	*Helianthus annuus* L.	Seed yield	0.75–1.0		S	Pathak et al., 1975
Sweet potato	*Ipomoea batatas* (L.) Lam.	Root DW	0.75–1.0		S	Eaton, 1944
Tobacco	*Nicotiana tobacum* L.	Laminae DW	2.0–4.0		MT	Eaton, 1944
Tomato	*Lycopersicon lycopersicum* (L.) Karst. ex Farw.	Fruit yield	5.7	3.4	T	Francois, 1984b
Turnip	*Brassica rapa* L. (Rapifera group)	Root DW	2.0–4.0		MT	Eaton, 1944
Vetch, purple	*Vicia benghalensis* L.	Whole plant DW	4.0–6.0		T	Eaton, 1944
Walnut	*Juglans regia* L.	Foliar injury	0.5–0.75		S	Haas, 1929
Wheat	*Triticum aestivum* L.	Grain yield	0.75–1.0	3.3	S	Bingham et al., 1985; Khudairi, 1961

[†] FW = fresh weight, DW = dry weight.

[‡] Maximum permissible concentration in soil water without yield reduction. Boron tolerances may vary, depending upon climate, soil conditions, and crop varieties.

[§] The B tolerance ratings are based on the following threshold concentration ranges: <0.5 g m^{-3} very sensitive (VS), 0.5 to 1.0 g m^{-3} sensitive (S), 1.0 to 2.0 g m^{-3} moderately sensitive (MS), 2.0 to 4.0 g m^{-3} moderately tolerant (MT), 4.0 to 6.0 g m^{-3} tolerant (T), and >6.0 g m^{-3} very tolerant (VT).

Table 3–6. Citrus and stone-fruit rootstocks ranked in order of increasing B accumulation and transport to scions[†].

Common name	Botanical name
Citrus	
Alemow	*Citrus macrophylla*
Gajanimma	*C. Pennivesiculata* or *C. moi*
Chinese box orange	*Severina buxifolia*
Sour orange	*C. aurantium*
Calamondin	*x Citrofortunella mitis*
Sweet orange	*C. Sinensis*
Yuzu	*C. junos*
Rough lemon	*C. limon*
Grapefruit	*C. x paradisi*
Rangpur lime	*C. x limonia*
Troyer citrange	*x Citroncirus webberi*
Savage citrange	*x Citroncirus webberi*
Cleopatra mandarin	*C. Areticulata*
Rusk citrange	*x Citroncirus webberi*
Sunki mandarin	*C. reticulata*
Sweet lemon	*C. limon*
Trifoliate orange	*Poncirus trifoliata*
Citrumelo 4475	*Poncirus trifoliata x C. paradisi*
Ponkan mandarin	*C. reticulata*
Sampson tangelo	*C. x Tangelo*
Cuban shaddock	*C. maxima*
Sweet lime	*C. aurantiifolia*
Stone fruit	
Almond	*Prunus duclis*
Myrobalan plum	*P. cerasifera*
Apricot	*P. armeniaca*
Marianna plum	*P. domestica*
Shalil peach	*P. persica*

[†]Data compiled from Embleton et al. (1973), and Hansen (1948, 1955).

certain trace elements may accumulate in the soil and/or crop to levels that pose a health hazard to its consumer. Molybdenum and Se are readily absorbed by plants and can be toxic to animals and humans (Page et al., 1990). If trace-element tainted drainage effluents are discharged into channels, lakes, ponds, estuaries or other bodies of water, there are ecological concerns that they may concentrate as they move up the food chain, a process called biomagnification.

The composition of salts in the drainage effluent can influence the uptake of certain trace elements by plants. Irrigation with drainage water dominated by sulfate-salts reduced selenate accumulation in vegetables (Burau et al., 1991). Preliminary studies with solution culture have shown that sulfate salinity also can reduce Mo accumulation in alfalfa shoots (Läuchli & Grattan, 1993, p. 105–114).

Some drainage effluents also have been found to contain high concentrations of U and V (Bradford et al., 1990), but it is still uncertain to what extent these elements would be accumulated in crops if these waters were used for irrigation.

IX. CONTROLLING SOIL SALINITY

Most of the crop salt-tolerance data provided in Tables 3–1 and 3–2 reflect how the plant responds to a relatively uniform soil-salinity profile from the seedling stage to harvest. Although useful, particularly for crop comparison purposes, field-grown crops respond to salinity profiles that change over time, making relative yield predictions understandably difficult. There are advantages, however, in imposing water management practices that allow salinity profiles to change over time as opposed to maintaining relatively constant soil salinity profiles. With controlled changes in soil salinity, crops with different tolerances to salinity can be included within a crop rotation (Rhoades et al., 1989). Increases in soil salinity also are acceptable when the tolerance of a crop increases within a season (Shennan et al., 1995). Adequate control of soil salinity changes requires that the farmer has access to multiple and dependable supplies of irrigation water where at least one supply is of good quality. Within limits, farmers that have irrigation water supplies of different qualities can use them alternately (cyclically) in different years, different times of the year or they can blend supplies to achieve a suitable quality water (Grattan & Rhoades, 1990). These strategies are discussed in more detail in Chapter 18 (Rhoades, 1999).

Regardless of the irrigation water supplies and quality available to the grower, irrigation practices must be managed to control soil salinity within an acceptable level. This requires that a favorable salt balance be attained. This does not suggest, however, that a calculated leaching requirement must be achieved each irrigation. Leaching fractions often decrease as the season progresses. In fact, it may be necessary to reduce the leaching fraction with a mature, deep-rooted crop actively growing in a soil with low permeability during months of high evaporative demand. Prolonged periods of saturation required to achieve leaching could produce anoxic conditions and encourage root disease. Nevertheless, a favorable salt balance must be maintained even if intermittent leaching (e.g., during the winter, alternate years, etc.) is the only means to remove excess salts from the soil.

A long-term salt balance can only be achieved at the farm scale or regional scale if there is adequate drainage. Crops grown in regions with saline water tables near the soil surface are subjected to salination if the water table rises. Crop production in these situations can not be sustained indefinitely since a long-term salt balance cannot be achieved. Use of saline water to irrigate crops grown in soils with high water tables accelerates the problem. Moreover, the required leaching further raises the saline water table, thereby salinizing the root zone. This paradox can only be overcome by adequate drainage and disposal, thereby ensuring that crop yields can be sustained over the long-term (van Schilfgaarde, 1990).

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ATTACHMENT H - *Effect of salt on soils*, California Agriculture (October 1984), pp. 11-13

table, produces conditions for accumulation of salts. Extensive borings along the west side reveal large concentrations of soluble salt and gypsum in some areas, as reported by L. D. Doneen and K. K. Tanji, of the Department of Land, Air, and Water Resources, UC Davis.

Although groundwater is widely used for crop production, surface water has been introduced from the Sacramento Valley through the Delta Mendota Canal, the California Aqueduct, and the East Side Canal. The salinity of this water is quite low — on the order of 230 mg/L — but the total salt imported is greater than 300,000 tons per year.

The system is gradually moving into a more critical stage, because conditions for additional deterioration are present. There are extensive areas where both excessively and slightly soluble salts are present and soils are slowly permeable. Importation of water brings in additional salt, releases immobilized salts in surface soils, increases the area affected by shallow water tables, and intensifies the hazards of salinity. Disposition of salts, water quality requirements, and the effect of salts on soils and plants are therefore of primary concern.

Disposition of salts

Problems and solutions of water and salt flow are site-specific. Evaluating the relative contributions of sources of salt to the root zone, to irrigation return flows, and to deep percolation and subsurface drainage is sometimes accomplished by salt and water balance methods. Salt balance methods are applied to both small-scale farm-size and large-scale river basin systems.

Irrigated areas develop problems when more salt enters the soil solution than is removed. Both concentration and type of salt are important. Soils and plants react differently to different salts.

Control of salt through removal by crops is not significant, since plants absorb only small quantities of salt. Although rainfall may be an important source of salt deposition in coastal areas, the real significance of rainfall in irrigated regions may often be associated with displacement of salt from the root zone and replenishment of the soil water. Rainfall may be as much as 30 percent more efficient for leaching salt than many irrigation methods, as shown by Miller, Biggar, and Nielsen, at UC Davis.

If irrigation is practiced in a particular area, it is implied that either rainfall is insufficient or water use does not coincide with the supply. This mismatch in use and supply may occur with respect to time as well as location. The importation of water into such a region inevitably leads to the development of shallow water tables and accumulation of excess salt. Irrigation water then becomes an important source of salt to the plant root zone, and the larger the concentration and volume of water applied, the greater the probability that problems will develop. Even after the initial reduction in native salinity found in soils of the west side of the Valley, water importation enhances the tendency toward increased area of perched water tables and accumulation of salt. In addition, problems of saline drainage water disposal and degradation of supply water become more critical.

Deposition of salt in the soil profile is partly a consequence of the differential removal of water by plant transpiration, leaving the salt in the soil. An irrigation water containing 100 mg/L total dissolved solids will deposit 0.136 ton of salt in the soil for each acre-foot per acre of water applied. Some cropping programs require 3 acre-feet of water annually; if the water contains 1,000 mg/L, a concentration common to many sources of water, 4.1 tons of salt will be applied to the soil in one season.

A shallow water table may inhibit plant growth because of excess salinity and water. Natural salinization of soils can result from shallow water tables and upward movement of water and salt due to evaporation and drying at the soil surface, conditions that exist in irrigated regions. Crops that derive part of their water requirements from shallow water tables are more salt-tolerant than others, but, depending on the saline content of the shallow water, even they will produce lower yields than under more favorable conditions.

Not all salt in the root zone comes from irrigation water or water tables. Some soils in their natural state contain varying quantities of slightly soluble solid forms of some salts, which continue to dissolve as water moves through the soil. In some places, these dissolving minerals, such as calcium sulfate, contribute more salinity to the soil solution and drainage water than is applied in the irrigation water. Areas on the west side of the San Joaquin Valley are noted for this effect.

Soil salinity control

A major process for salinity control depends on leaching water through the root zone to remove excess salt and limit the dissolved salt content to the tolerance limits of the crop to be grown. Movement of water through the profile is necessary to remove excess soluble salt from the root zone of crops but is undesirable when it dissolves precipitated salts, since excess water and salt increase drainage requirements and the salt degrades groundwaters.

It is prudent to minimize the flow of water through the soil profile to reduce dissolution of soil minerals and promote precipitation of slightly soluble carbonates and sulfate minerals in the profile. Since precipitated minerals have little effect on plant growth or soil properties, the reduction in salt load should be beneficial to groundwater and surface flows. Unfortunately, neither of the mentioned processes can prevent a soil from eventually becoming salinized. Some means of collecting saline drainage waters is essential to balance salt inflow and outflow and maintain a favorable salt environment in the root zone of a crop. In some cases, crop selection may be dictated by the achievable salt balance, but the higher the concentration of soluble salts in the root zone, the narrower the choice of crops and the smaller the economic returns.

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Effect of salt on soils

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When water is applied, particles of soils with high smectite (montmorillonite) clay content may swell considerably due to hydration of expandable soil minerals. Such swelling reduces the cross-sectional area of soil pores. The process of swelling is more pronounced in the presence of high sodium or low salt concentrations, or both, in the soil water.

Dispersion of fine soil particles is controlled by a similar mechanism. Dispersion is directly influenced by ions adsorbed on particle surfaces, particularly clay minerals. The presence of high sodium, especially at low salt concentration in the soil water, causes dispersion and movement of fine particles within the pores. The particles may then become lodged in smaller pores, blocking water or air.

Swelling and dispersion are both in-

Salinity swells soil clays, leading to crust formation and reduced water transmission through the soil.

fluenced by clay mineralogy, the amount of sodium adsorbed on the soil, and the salt concentration in the soil water. In general, dispersion is greater in smectite clays than in kaolinite clays, and in kaolinite clays than in micas. Considerable dispersion and swelling may occur with only small amounts of sodium adsorbed on the soil if the concentration of salt in the soil water is very low, approaching that of rainwater. Less swelling and dispersion will occur with increasing concentrations of salt in the soil water.

Dispersion and swelling are major mechanisms by which surface soil aggregates break down. The resulting surface seals and crusts act as layers impeding infiltration of water into the soil, diffusion of gases across the soil surface, and emergence of plant seedlings. The impact of rain or sprinkler irrigation drops and irrigation water flowing over the surface soil dislodges soil particles from aggregates through physical forces, air entrapment, dispersion, and swelling. Once the particles are dispersed, some may be moved into pores. The force of the water drops may also compact a thin layer of soil Other dispersed particles remain at the surface and settle as the surface water infiltrates, with some orientation of the clays to form a dense layer of soil a few millimeters thick. Although surface crusts occur in areas where salinity is not considered a problem, the amount of sodium and concentration of salt in rain or irrigation water will indirectly influence the degree of particle dispersion and the development of surface sealing or crusts.

Surface seals or crusts limit the movement of gases in and out of the soil profile, especially under wet conditions following irrigation or rainfall. Unless the crust cracks as the soil dries, the low rate of oxygen movement across the soil surface may result in temporarily poor aeration within the root zone and adversely affect the crop.

Swelling and dispersion of soil clays affect water transmission properties by altering the geometry or continuity of soil pores. The hydraulic properties of soil, such as hydraulic conductivity, are thus highly dependent on both the exchangeable sodium percentage and the salt concentration of the percolating soil solution. The rate of water flow through soils with a high exchangeable sodium percentage may be maintained, if the concentration of salt in the percolating solution is above a threshold value where swelling and particle dispersion are limited. However, in soils with low exchangeable sodium percentages, clay dispersion and the resulting decrease in hydraulic conductivity will occur at very low salt concentrations in the percolating solution, just as they do at high exchangeable sodium percentages and low salt in the water.

Soils of the east side of the San Joaquin Valley contain clay minerals that are easily dispersed, resulting in water absorption problems that are not readily avoided. The predominant montmorillonite soils on the west side respond to proper management of sodium and salinity.

California and Israeli researchers have recently determined that when the percolating solution is very low in salt, such as in rainwater, the susceptibility to decreased water flow due to presence of absorbed sodium depends on the potential of the soil to release salt. The released salt or electrolyte is derived from weathering of primary minerals and dissolution of calcium carbonate. If electrolyte is released at a rate sufficient to maintain the concentration of salt in the percolating solution above the level where particle dispersion occurs, the rate of water flow through the soil can be maintained at acceptable levels. Highly weathered or old soils tend to release electrolyte at a lower rate than young or calcareous soils and those with primary minerals such as feldspars and plagioclases.

The water infiltration characteristics of a soil strongly influence the type and management of the irrigation system. Soils with a moderate exchangeable sodium percentage may have reasonable water transmission rates below the soil surface due to release of electrolyte from soil minerals. Yet these same soils may have very low infiltration rates at the soil surface because of high particle dispersion and sealing caused by rainfall or irrigation water of very low salt concentrations. The presence of sodium bicarbonate in well waters along the east side of the Central Valley increases the tendency for crust formation as well as reduced permeability with depth.

Salinity might be expected to have a detrimental effect on the activity and efficiency of microorganisms responsible for nutrient cycling within soils. However, most evidence from UC research indicates that soil microorganisms are affected only at very high concentrations of salt in the soil.

K. K. Tanji (Department of Land, Air and Water Resources, UC Davis) has made detailed analyses of the salt disposition in the Panoche Drainage District. Situated in one of the salt-affected regions of the Valley, this district encompasses three irrigation districts that use a number of sources, including imported

Delta Mendota and California Aqueduct water. The supply water averaged 234 mg/L in salinity, and the soil water, assuming a doubling or tripling in concentration due to evapotranspiration, would be expected to reach nearly 700 mg/L. However, measurements and model calculations demonstrated the soil water to be 7,000 to 8,000 mg/L. This is water that would penetrate deeper into the profile and that would be captured by drains to be discharged elsewhere or recycled for crop production. The 10-fold increase in concentration is attributed to dissolution of soil minerals, principally gypsum. Although a few crops could tolerate such concentrations for selected periods, the long-term maintenance of irrigated agriculture using such waters is doubtful.

In summary, the major effects of salinity on soil properties are swelling of soil clays, dispersion of fine soil particles, crust formation, and decreases in water-transmission properties. The amount of sodium adsorbed on the soil and the amount of sodium and salt in the irrigation water greatly influence the degree to which salinity affects soil properties.

Dennis E. Rolston, J. W. Biggar, and Donald R. Nielsen are Professors, Department of Land, Air, and Water Resources, University of California, Davis.

Case history: Salton Basin

Jewell L. Meyer **Jan van Schilfgaarde**

The Salton Basin extends 200 miles from San Gorgonio Pass in the north through the Coachella, Imperial, and Mexicali valleys to the Gulf of California. The basin covers a drainage area of about 8,000 square miles and at its deepest point is 273 feet below sea level — about the same as Death Valley.

The desert climate is characterized by long hot summers, short mild winters, and sporadic rainfall averaging only about 3 inches per year. If water can be supplied, the climate and alluvial soil are ideal for many vegetable, fruit, and field crops.

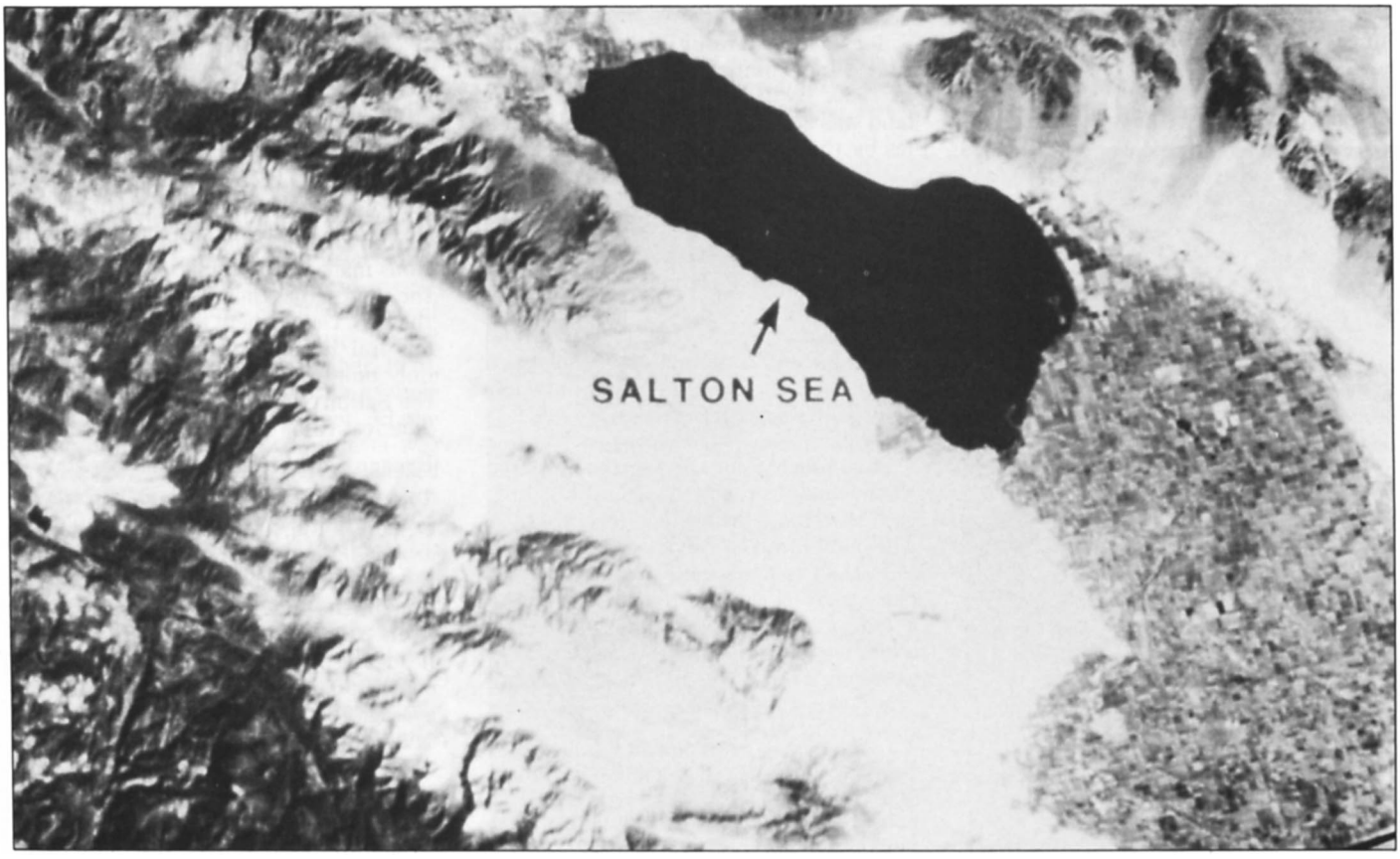
Irrigation water delivery to the Imperial Valley began in June 1901. Within three years, over 150,000 acres were being planted to barley, grain sorghum, alfalfa, and cantaloupes, despite problems with transportation and water delivery, and severe living conditions for the new settlers.

In March 1905, silt that had built up in the Colorado River near the headgates south of Yuma, Arizona, diverted the first of several floods into the canal system. Flood water flowed through the canals and the Alamo River into the Salton Sea, cutting a new, 60-foot gorge, the New River. The Salton Sea, nearly dry in 1904, filled to a level of −195 feet; the sea covered 500 square miles and was 80 feet deep by early 1907, when the Southern Pacific Railway Company finally closed the breach.

The Imperial Irrigation District, formed in 1911, had consolidated most of the mutual water districts under a single entity by 1916 and enlarged its potential boundaries to over ½ million acres. With federal assistance, Imperial Dam was built on the Colorado River and the All-American Canal was constructed. Water delivery to the Imperial Valley through these facilities started in 1943.

In contrast to the Imperial Valley,

The 8,000-square-mile Salton Basin, one of the most productive agricultural areas in the world, as seen by a Landsat camera. The Salton Sea serves as the drainage basin for saline irrigation waters from the Imperial, Coachella, and Mexicali valleys.



Appendix L – Exhibit 19 of the James Irrigation District Comment Letter

FRIANT WATER AUTHORITY

EVALUATION OF IMPACTS FROM USE OF RE-CIRCULATED SAN JOAQUIN RIVER WATER

NOVEMBER 2012

DATE SIGNED: 11-7-2012

PREPARED BY:

PROVOST AND PRITCHARD
CONSULTING GROUP

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LIST OF ABBREVIATIONS

AEWSD	Arvin-Edison Water Storage District
AF	Acre-feet
CVC	Cross Valley Canal
CVP	Central Valley Project
CV-SALTS	Central Valley Salinity Alternatives for Long-Term Sustainability
DEID	Delano-Earlimart Irrigation District
DWR	Department of Water Resources
EC	Electrical conductivity
FKC	Friant-Kern Canal
FWA	Friant Water Authority
FWUA	Friant Water Users Authority
GAMA	Groundwater Ambient Monitoring and Assessment
ILRP	Irrigated Lands Regulatory Program
KDWD	Kern Delta Water District
KTWD	Kern-Tulare Water District
LR	Leaching Ratio
LTRID	Lower Tule River Irrigation District
MCL	Maximum contaminant level
MUD	Municipal Utility District
MWDSC	Metropolitan Water District of Southern California
NPDES	National Pollution Discharge Elimination System
O&M	Operation and maintenance
P&P	Provost & Pritchard Engineering Group
PEIR	Programmatic Environmental Impact Report
PID	Pixley Irrigation District
RWQCB	Regional Water Quality Control Board
RRBWSD	Rosedale-Rio Bravo Water Storage District
SAR	Sodium Absorption Ratio
SJR	San Joaquin River
SSJMUD	Southern San Joaquin Municipal Utility District
SWID	Shafter-Wasco Irrigation District
SWP	State Water Project
SWRCB	State Water Resources Control Board
TDS	Total dissolved solids
TSS	Total suspended solids
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture

EXECUTIVE SUMMARY

This study evaluates the impacts from using "re-circulated" San Joaquin River water in the Friant service area of the Central Valley Project. Re-circulated San Joaquin River water (Re-circulated Water) is water released from Millerton Lake and Friant Dam as part of the San Joaquin River Restoration Settlement to partially mitigate Friant contractors for lost water supplies. The water is assumed to be recaptured in the Delta and returned to the Friant Service area through the California Aqueduct and Cross Valley Canal (CVC).

Re-circulated Water will have different water quality than the San Joaquin River water it replaces, and may or may not have impacts on Friant contractors that would require mitigation. This study evaluates potential impacts to crop yields, corrosion, distribution systems, groundwater quality, and water management programs from use of Re-circulated Water in the Study Area.

Five Friant Division contractors located in Kern and Tulare Counties, California could potentially receive Re-circulated Water and were evaluated in this study. These agencies include: Arvin-Edison Water Storage District (AEWSD), Shafter-Wasco Irrigation District (SWID), Southern San Joaquin Municipal Utility District (SSJMUD), Kern-Tulare Water District (KTWD), and Delano-Earlimart Irrigation District (DEID).

Water Quality

The two water sources compared in this study are San Joaquin River/Millerton Lake water delivered through the Friant-Kern Canal (FKC), and Re-circulated Water. Re-circulated Water would likely mix with other water supplies in the Delta, O'Neill Forebay and San Luis Reservoir during transit through the California Aqueduct to the Cross Valley Canal. Therefore, it was assumed to have the same quality as State Water Project (SWP) water.

SWP water quality was evaluated over the last thirty-two years (1980-2011) and more specifically the last ten years (2002-2011) at Check 21 (near Kettleman City) on the California Aqueduct. FKC water quality was evaluated from 1957-2004 at Milepost 122.05 near Woollomes Check on the FKC. SWP water is higher than FKC water in most constituents. For instance, TDS values average 256 mg/l (SWP) compared to 45 mg/l (FKC). SWP water quality varies monthly with the water quality generally better than average during the summer and worse in the winter. Monthly variations were considered in evaluating agronomic impacts, but annual averages were used to evaluate groundwater quality and operation and maintenance impacts, since these impacts gradually occur over long time periods, and are less impacted by periodic highs and lows in water quality. Pump-in programs along the CVC could reduce the quality of Re-circulated Water, but this impact was not evident in the limited CVC water quality data available.

Re-circulated Water Supplies

Three water supply scenarios were evaluated. Each assumes that pumpback facilities are in place in the Friant Kern Canal. The three scenarios include:

Case 1: Maximize Re-circulated Water deliveries directly to AEWSD.

Case 2: Maximize Re-circulated Water deliveries to Friant-Kern Canal for pumpback operations.

Case 3: Apportion deliveries based on each agency's water supply impacts from providing Restoration flows. This scenario is theoretical, because the Re-circulated Water cannot physically be delivered to all districts that provide restoration flows, but this scenario does represent what each Friant contractors should have expected to deal with.

Based on studies by the U.S. Bureau of Reclamation (USBR), average-annual Re-circulated Water deliveries are estimated to be 58,400 AF/year. Actual deliveries will vary with hydrology and are expected to range from 0 to about 250,000 AF/year. Following is a summary of anticipated water deliveries for the three cases. Case 1 and Case 2 are based on the results of hydrologic models prepared by the USBR.

Table ES-1 – Summary of Re-circulated Water Deliveries

District	Average Annual Deliveries (AF)		
	Case 1	Case 2	Case 3
AEWSD	34,600	26,100	8,700
SWID	6,800	8,500	2,000
SSJMUD	6,600	10,200	3,300
DEID	3,100	5,300	4,100
KTWD	1,300	2,100	-
"Surplus"	6,000	6,200	-
Total	**58,400**	**58,400**	**18,100**

Note: Surplus water is not delivered to any district due to lack of demand or delivery capability.

The following observations were drawn from this study with regards to receiving Re-circulated Water of SWP quality:

Regulatory Impacts

- Groundwater salinity will increase annually under this program. The anticipated annual increases in salinity however will not exceed the allowable rate of annual increases cited in the Water Quality Control Plan for the Tulare Lake Basin (Basin Plan). The Basin Plan, however, will be amended in the future with regulations being developed by the CV-SALTS program. The CV-SALTS

program is focused on addressing the long-term degradation of groundwater supplies due to the importation of salts, among other things. The details of the CV-SALTS program are not yet available, however this program, if implemented, could potentially be problematic for the participating districts that receive Re-circulated Water.

- The increases in groundwater salinity will have to comply with the State's Anti-Degradation Policy which could feasibly be used to restrict Re-circulated Water imports to the Friant Division service area. In that event, it would have to be demonstrated and determined by the SWRCB that salinity degradation due to Re-circulated Water deliveries are consistent with "the maximum benefit to the people of the State". No such determination has been made to date and if such a determination was sought there is a potential for protests and conflict among Friant districts.
- Drafting of provisions for the Irrigated Lands Regulatory Program (ILRP) are currently underway and slated to be adopted by the Regional Board. Among other things, this program is intended to enforce management of nitrogen on farm. Re-circulated Water is on average 4 times higher in nitrogen than FKC water, so its delivery could work in direct conflict with ILRP mandates. Some potentially impacted lands are already designated as "High Vulnerability Areas" under the draft ILRP.
- Currently the movement of water from one watershed to another, such as with Re-circulated Water, is exempt from NPDES permits. Elimination of this exemption could be problematic for conveyance of Re-circulated water if it became necessary to obtain an NPDES permit.

<u>Agronomic Impacts</u>

- While SJR water is of consistently high quality for irrigating even the most sensitive crops, Re-circulated Water should also be adequate for irrigation of virtually all crops, however Re-circulated Water has a higher mineral content than SJR water and some specific constituents can reach levels of concern for some sensitive crops under certain conditions. Mitigation practices, including monitoring, blending, avoidance, and irrigation system changes may sometimes be required.
- Re-circulation Water will occasionally have specific ion concentrations and salinity in the "slight to moderate restriction on use" range. Sprinkler irrigated fruits and vegetables would be the most sensitive and also can be susceptible to cosmetic "white wash" under certain conditions. It is anticipated that maximum concentrations in Re-circulated Water would not be sustained for long periods of time, but the most sensitive crops could experience some potential impacts if Re-circulation Water was used for the whole crop season.

- Re-circulated Water has higher pH levels which increases the potential for plugging of emitters. Mitigation practices, such as increased acid injection, may be required.
- Minor increases in the corrosion of metal components of district and on-farm irrigation systems (in pumps, filter stations, pipelines, fittings, and valves) could occur if a significant amount of SWP quality water is delivered. At the same time, there could be reduction in erosion rates of concrete facilities and reduced damage to aluminum sprinkler lines when irrigating with fertilizers as a result of an increase in the use of SWP quality water.
- SWP quality water has better infiltration characteristics than does CVP SJR water and helps maintain soil structure because of the higher mineral content. However, as the salinity of the irrigation water increases, the amount of water needed for leaching also increases. Differences in mechanical compaction would be expected to be minor, and, if anything, improved by use of SWP quality water.
- The use of SWP quality water has the potential to reduce the need for use of gypsum, manure, and green waste for combating infiltration problems for most of the studied district area, although growers are not likely to make significant changes in their soil amendment applications for a variety of reasons. Organic production that relies on manures and composts for supplying required crop nutrition are also unlikely to reduce use of these amendments even with the contemplated change in water source. It should be noted however that much of the salt in the SWP water is, pound for pound, potentially more damaging than the salts in gypsum.
- SWP quality water has higher salinity and thus higher leaching requirements than CVP SJR water. Lands with low irrigation distribution uniformity may require higher leaching amounts. From a practical standpoint however, it may be that current crop rotations and crop establishment practices, irrigation non-uniformity and certain cultural practices such as winter irrigation for frost control and recharge of permanent crop root zones are adequate to cover the extra 5 percent to 6 percent leaching requirement needed for sensitive crops that use only SWP quality water.

<u>Corrosion Impacts</u>

- SWP quality water will have less potential to leach minerals from concrete and cement mortar than San Joaquin River water.
- SWP quality water would cause higher corrosion to some metals than San Joaquin River water.
- The increase in corrosion can be managed with coatings and selection of proper materials for new equipment. Operation and maintenance costs may increase, primarily to manage protective coatings, but the increase is estimated to be less than 10 to 15 percent over current costs.

Distribution Systems Impacts

- Additional sediment accumulations in pipelines, canals, reservoirs and recharge basins would be negligible, but some accumulations could occur in localized areas, such as turnouts, forebays, standtanks, and subsidence areas.
- Abrasion and wear on equipment does not appear to be a problem with either water source.
- Algae growth is likely a larger problem with CVP SJR water due to its high clarity, but is still present in SWP quality water, and can be effectively treated with copper sulfate.
- Infiltration rates have the potential to change, which could impact seepage in canals, reservoirs and recharge basins. However, the magnitude of the change is difficult to quantify because it depends to varying degrees on several parameters (biological growth, salinity, sediment content, and temperature).

Groundwater Quality Impacts

- Importing Re-circulated Water is estimated to increase groundwater salinity. The rates will vary by studied district, aquifer assumptions, and the assumed water supply scenario, but under the scenarios studied herein the rate of increase would range from 0.1 to 1.1 mg/l/year in the shallow groundwater, and from 0.0 to 0.2 mg/l/year in the entire saturated thickness. Salinity increases are lower when they are assumed to be distributed over the entire aquifer thickness, however, the salts will likely accumulate in the shallow aquifer.
- Additional salts will be imported with the re-circulated water. One scenario estimates that an average of 13,700 tons/year will be imported into the studied districts. While this report attempts to study effects of certain scenarios, and specific assumptions, the fact remains that exchanging SWP water for FKC, regardless of the timing, flow rate, or receiving District, will bring with it an increase in salt load.
- Local groundwater levels will be impacted with San Joaquin River restoration flows even when the mitigation waters (Re-circulated, 16(b), and P3 waters) are considered. Annual groundwater level declines resulting from surface water supply reductions from the San Joaquin River Settlement are estimated to range from 0.3 feet/year in SSJMUD to 1.0 feet/year in AEWSD. It is expected that native groundwater quality will decline with declining water tables.

Water Management Program Impacts

- Numerous water management programs, such as transfers, exchanges and wheeling agreements, could be impacted by the delivery of Re-circulated Water,

increasing competition for conveyance and storage facilities and reducing the water desirability for exchange partners from a water quality standpoint.

- Exchanges or transfers that are intended to provide high quality CVP SJR water could be significantly impacted if Re-circulated Water is delivered instead. The water quality benefits to Metropolitan Water District of Southern California from existing exchange/banking programs with AEWSD could be significantly reduced given a lesser availability of CVP SJR supplies to exchange.
- A principal conveyance impact would likely occur from anticipated reverse flows in the southern portion of the FKC. This could inhibit some existing water management programs that rely on forward flow conditions.
- Possible impacts to KTWD could be significant. These impacts would include increased competition for CVC capacity and exchanges with other Friant districts, which could significantly increase water costs for KTWD.
- The impacts to water management programs will depend on the timing and quantity of Re-circulated Water delivered each year. The timing is difficult to predict and will vary each year, making water management programs difficult to manage or plan. The quantity of Re-circulated Water will average about 10-15 percent of the impacted District's CVP water supply.

Distribution of Re-circulated Water

The studied districts would receive 18,100 AF/year of Re-circulated Water if it was apportioned among and directly delivered to all parties impacted by the San Joaquin River Settlement. However, as this is not feasible, the studied districts will likely receive the full brunt of about 52,400 AF/year of Re-circulated Water. This is approximately 290 percent of the water they would receive through an apportioned distribution. The impacts described above are based on deliveries of about 52,400 AF, but would be lower if only 18,100 AF was delivered. It should be further noted that the more southern studied districts will receive "full strength" higher salinity water while more northern studied districts may benefit from some amount of dilution with FKC water.

Economic Impacts

Most of the impacts described above could result in extra costs or revenue losses for growers. Extra costs could include water and energy for extra leaching, management of higher nitrogen and pH levels, repairing plugged emitters, etc. Revenue losses could include lower crop yield and lower crop quality. Quantifying these costs is beyond the scope of this study. However, the results of this study are believed to provide the basis for beginning the negotiation of a mitigation program.

1 - INTRODUCTION

1.1 - Overview

This study evaluates the impacts from using "re-circulated" San Joaquin River water in the Friant service area of the Central Valley Project. Re-circulated San Joaquin River water (Re-circulated Water) is water released from Friant Dam as part of the San Joaquin River Restoration Settlement, has been recaptured at one or more locations downstream of the Dam, and subsequently delivered back to the Friant service area. This includes water that flows into the Sacramento-San Joaquin Delta, is pumped from the Delta at either the State or Federal pumping plants, and is subsequently delivered into the Friant-Kern Canal via the California Aqueduct and Cross Valley Canal. Re-circulated Water also includes water that could be recaptured at multiple locations along the San Joaquin River and delivered to Friant Contractors by other mechanisms but is not a part of this study. For purposes of this study, and because all possible sources would be blended in O'Neill Forebay (a point on the State and Federal water projects where water is comingled/mixed and put into joint storage in San Luis Reservoir), it is assumed that all Re-circulated Water originates from the Delta. Pumpback facilities are assumed to be constructed on the Friant-Kern Canal to lift the water over three existing check structures and reverse flow the Friant-Kern Canal up to Lake Woolomes to deliver the Re-circulated Water to select districts in-lieu of delivering water from Millerton Lake.

The river restoration will require certain flows in the San Joaquin River for fisheries habitat and thus will reduce the quantity of water that Friant contractors can divert from Friant Dam for agricultural or municipal uses. The Re-circulated Water is intended to reduce or avoid impacts to Friant Division contractors that have had their diversions reduced. However, the Re-circulated Water would have different water quality than water delivered directly from Millerton Lake, and may or may not have impacts on the parties receiving the Re-circulated Water that would require mitigation. This study specifically evaluates impacts to crop yields, corrosion, distribution systems, groundwater quality, and water management programs from the use of Re-circulated Water in the Friant service area in lieu of their normal Friant Division Millerton Lake diversions.

1.2 - Plan Area

Five Friant Division contractors located in Kern and Tulare Counties, California could potentially receive Re-circulated Water assuming pumpback facilities are constructed on the Friant-Kern Canal over three existing check structures. These agencies include:

- Arvin-Edison Water Storage District
- Shafter-Wasco Irrigation District
- Southern San Joaquin Municipal Utility District
- Kern-Tulare Water District

- Delano-Earlimart Irrigation District

Refer to **Figure 1.1** for a map showing the locations of these districts. This study evaluates impacts to these districts and the lands they serve and are hereafter called the 'studied districts'. Additional background information on these districts is presented in Section 2.2.

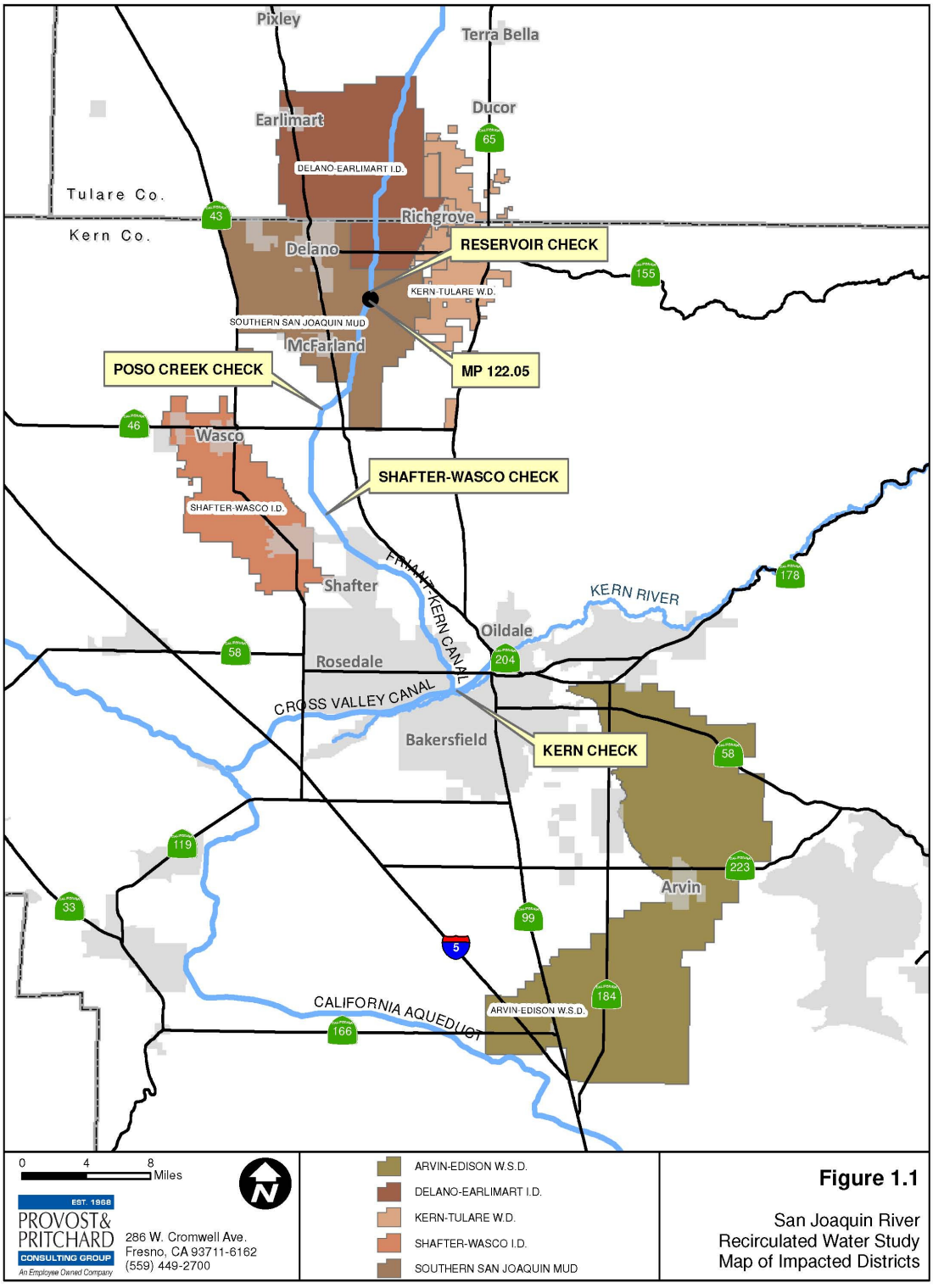


Figure 1.1 – Map of Studied districts

1.3 - Previous Study – Analysis of Impacts from Changed Source Waters

In May 2006, the Friant Water Users Authority (FWUA) (now Friant Water Authority - FWA) performed a study evaluating a potential water exchange that would import significant quantities of Delta water into the Friant Service area. The trading partner was proposed to be the Metropolitan Water District of Southern California (MWDSC), who was interested in exchanging State Water Project (SWP) water for San Joaquin River water because of the superior water quality of the San Joaquin River. This study was intended to be the first of a three phase study, and is hereafter called the 'Phase I Study'. The Phase I study was documented in a series of reports entitled *Analysis of Impacts from Changed Source Waters*. These reports and an Executive Summary for the overall study are provided in **Appendix A**. The water exchange was not implemented and there are no current plans to resurrect the project. However, the study provides data and analyses that can be used for evaluating the use of Re-circulated Water supplies in the Friant service area. This new study and the Phase I Study investigated the same impacts including agronomic, operation and maintenance, groundwater, water quality, and water management impacts. This new study will use many of the same analyses methods, and rely on the Phase I study for much of the supporting analyses, but will be based on a different quantity and timing of Delta water supplies as it relates to the Re-circulated Water.

The Phase I Study evaluated impacts to the agencies listed in Section 1.2, in addition to Lower Tule River Irrigation District (LTRID) and Pixley Irrigation District (PID). However, LTRID and PID were not included in this study because they are assumed to have little to no potential for receiving Re-circulated Water because the planned pumpback facilities cannot pump the Re-circulated Water back up the Friant-Kern Canal near LTRID and PID turnouts. Other potential exchange opportunities were deemed not to be considered by FWA to be part of the study.

Several experts peer reviewed the Phase I study, but their comments had not been incorporated when the study was suspended. However, these comments have the potential to strengthen the analysis, and improve the accuracy of the results. As a result the peer review comments were reviewed and significant and relevant comments were used to refine and improve the analysis used in this Re-circulated Water study. The responses to the most important peer review comments pertaining to this study are provided in **Appendix B**.

1.4 - Scope of Work

The general scope of work for this study includes the following:

1. Discuss the relevance of regulatory policies and programs on the use of Re-circulated Water in the Friant Division service area.
2. Identify the timing and volumes of Re-circulated Water likely to be imported into each of the studied districts.

3. Review previous Phase I peer review comments on corrosion, distribution systems, groundwater, and agronomic impacts, and incorporate relevant comments into this analyses.
4. Perform water and salt balance calculations to determine potential groundwater salinity impacts.
5. Evaluate agronomic, operation and maintenance, and water management impacts from the use of Re-circulated Water in the Friant Division service area.

2 - BACKGROUND INFORMATION

2.1 – Water Quality

The two water sources compared in this study are San Joaquin River/Millerton Lake water delivered through the Friant-Kern Canal, and Re-circulated Water, which is assumed to originate in the Delta and be delivered through the California Aqueduct and Cross Valley Canal. Re-circulated Water would likely be delivered to O'Neill Forebay and San Luis Reservoir during transit to the Cross Valley Canal. The Re-circulated Water would therefore have opportunities to mix with Delta water in the Delta, in the Delta Mendota Canal (given the newly constructed Intertie facilities), California Aqueduct/San Luis Canal, in O'Neill Forebay, and in San Luis Reservoir and therefore can be assumed to have the same quality as Delta originated supplies as represented by State Water Project (SWP) water. This represents the "worst case" condition in terms of changed quality, and is reasonable since there is no guarantee that water delivered down the San Joaquin River would be able to be diverted anywhere upstream of the Delta for re-circulation. Table 2.1 compares average concentrations of major constituents in each compared water source.

Table 2.1 – Water Quality Comparison of Selected Water Sources

Constituent	Unit	California Aqueduct (State Water Project)[1]	Friant-Kern Canal (San Joaquin River)[2]	Irrigation Suitability[4]	California Drinking Water MCLs[5]
Alkalinity	(mg/l as $CaCo_3$)	73	n/a	-	None
Bicarbonate (calc)	mg/l	84	16	-	
Boron	(mg/l)	0.2	0.07	<0.7	None
Calcium	(mg/l)	19	4.6	-	None
Chloride	(mg/l)	69	4.2	<107	250[6]
Electrical Conductivity	(uS/cm)	449	67	<700	None
Hardness	(mg/L as $CaCo_3$)	99	15	-	None
Magnesium	(mg/l)	12	0.8	-	None
Nitrate	(mg/l)	2.8	0.7	<5	10
pH	-	7.6	7.0	6.5-8.4	<6.5 and >8.5[6]
Sodium	(mg/l)	49	3.8	<69	None
Sodium Absorption Ratio	-	2.2	0.4	3	None
Sulfate	(mg/l)	37	3.7	-	250[6]
Total Dissolved Solids	(mg/l)	256	45[3]	<450	500[6]

Notes:
1) California Aqueduct Check 21 (Milepost 172.40 near Kettlemen City/Hwy 41), average 2002 – 2011, data provided by the California Department of Water Resources.
2) Friant-Kern Canal Milepost 122.05 (just downstream of Woolomes Check), average 1957-2005, data provided by the Friant Water Authority
3) AEWSD records show a range of 13 to 37 mg/l, with an average of 22 mg/l.
4) Food and Agriculture Organization of the United Nations, Water Quality for Agriculture, FAO Irrigation and Drainage Paper 29, 1985. Values are for no degree of restriction on use.
5) California Department of Public Health, California Regulations Related to Drinking Water, 6,21, 2012
6) Denotes a secondary MCL

Appendix F includes the detailed historical data used to develop these average values. Section 6 – Agronomic Impacts includes monthly data for some constituents important to crop growth.

Throughout this document the terms 'SWP quality water' and 'Re-circulated Water' are used. 'SWP quality water' is used when referring to historical SWP water quality and water deliveries. 'Re-circulated Water' refers to re-circulated San Joaquin River water that would be delivered in the future. The term 'San Joaquin River water' or 'CVP SJR

water' refers to San Joaquin River water delivered from Millerton Lake through the Friant-Kern Canal.

State Water Project Water Quality

Re-circulated San Joaquin River Water could be delivered to the California Aqueduct for return to the Friant Division through two primary methods: 1) water flowing all of the way to the Delta and then pumping it into the California Aqueduct; and 2) pumping water out of the San Joaquin River upstream of the Delta and delivering it through a canal or pipeline into the California Aqueduct. It shall be noted that both options can deliver water to the Delta Mendota Canal and then back into the California Aqueduct via the newly constructed Intertie facilities between both canal systems. Water flowing to the Delta would mix within this large water body and any quality differentiation would be essentially lost. Consequently, the water quality would likely be similar to long-term Delta water, with no real effect from mixing with San Joaquin River water. Water re-captured upstream of the Delta could have some immediate impact on California Aqueduct water quality, although it would be minimized as the water is mixed in with significantly larger volumes of Delta originated supplies in the canals, O'Neill Forebay and San Luis Reservoir. In addition, limited facilities are in place to recapture water in the San Joaquin River. Thus in this study, it is assumed that all waters are assumed sent to the Delta, and the Re-circulated Water has the same quality as SWP supplies have had on average over the long-term.

SWP water quality data was obtained from monthly grab samples collected by the Department of Water Resources (DWR) at California Aqueduct Check 21 from 1980 through 2011. Check 21 (Milepost 172.40) is located near Kettlemen City/Highway 41 and is the nearest monitoring location upstream of the Tupman/Cross-Valley Canal (CVC) turnout (Milepost 238.04), although they are nearly 66 miles apart. Water quality at this location would be most representative of the quality of water that could be delivered into the CVC and hence Friant Division service area from the Re-circulated Water program.

The SWP water quality data from 1980-2011 is a 32-year long-term average that covers multiple water year types and changes in Delta operations. A copy of the SWP water quality data for the years 1980-2011 is contained in Appendix F. SWP water quality data from 1994-2003 was used for analysis of impacts in the Phase I Study and is only included herein for comparison purposes. SWP water quality data from 2002-2011 is the most recent 10-year period available after implementation of the Bay-Delta Accord and is considered representative for current and future conditions for pumping out of the Delta and as such, was used for this analysis of potential impacts resulting from the use of Re-circulated Water.

The average SWP water quality is very similar between all periods analyzed. However, the maximum values measured in the monthly grab samples during the 2002-2011 period were lower and the minimum values were higher than during the other periods that included data prior to 2002. In fact, nearly all of the highest

maximum values were measured in the 1980's to mid-90's (as shown in the data contained in Appendix F), and it appears that many of the higher maximum values can be attributed to a single event in 1995 which may have involved floodwater entering the California Aqueduct. It shall be noted that SWP water quality could change significantly in some years as a result of dry year pump-in programs such as the Semitropic Water Storage District program (near Milepost 209). The pump-in programs must satisfy minimum water quality requirements enforced by the Department of Water Resources, and impacts may not be evident in long-term data if the pump-ins occur for short time periods.

Values in Table 2.1 are averages over a 10-year period. A review of monthly SWP water quality data shows that it varies by month, with the water quality being generally better than average during the summer and worse than average in the winter. The average monthly water quality was used in the agronomic impacts analysis (Section 6). The annual long-term average values in Table 2.1 were used in analyzing groundwater quality and operation and maintenance impacts, since these impacts gradually occur over long time periods, and are less impacted by periodic highs and lows in the water quality.

Cross Valley Canal Water Quality

Water conveyed in the Cross Valley Canal (CVC) could be impacted by numerous pump-in programs along the CVC. Rosedale Rio Bravo Water Storage District (RRBWSD) is one agency that has a CVC pump-in program. Source water quality from pump-in wells in RRBWSD in 2007 was compared to SWP water quality. The well water had lower TDS than SWP water (~150 mg/l versus 256 mg/l). However, several constituents had higher values at times compared to SWP average values including calcium (29 mg/l versus 19 mg/l), nitrates (8.6 mg/l versus 2.8 mg/l) and pH (8.3 versus 7.6). These conditions may occur at certain times, especially when pump-in programs provide the majority of water in the CVC.

Due to the potential impacts from pump-in programs, CVC water quality was compared to SWP water quality at California Aqueduct Check 21. The CVC water quality samples were collected between 2001 and 2011 at the AEWSD turnout, CVC Pumping Plant No. 6, locations near the Friant-Kern Canal, and at the Garnett Water Treatment Plant (terminus of CVC). Overall the data is limited and was not collected on a regular basis. This data is provided in **Appendix F** with comparisons to SWP water. The CVC water quality was very similar to the water quality at Check 21. As a result, data from Check 21 was used in the analysis and is used throughout this report. Check 21 data was also used in the Phase I Study. Negative impacts from pump-in programs are not reflected in the data, although that may be because the data is sparse.

San Joaquin River Water Quality

San Joaquin River water quality is based on samples collected along the Friant-Kern Canal (FKC). The data are based on average annual values collected each year (with the exception of a few years) from 1957 through 2004. The samples were collected by

the USBR and FWA at Mile Point 122.05 (downstream of Lake Woolomes Reservoir Check, the furthest planned upstream pumpback location along the Friant-Kern Canal (see Figure 1.1). Mile Point 122.05 is located in Southern San Joaquin Municipal Utility District, and is generally centrally located among the studied districts.

Typically, the FKC water quality does not change appreciably between Lake Woollomes and the canal terminus, based upon data in a 2009 USBR report entitled "*Baseline Water Quality Report for the Central Valley Project, 1996-2008*". Therefore, using the data from Mile Point 122.05 is considered appropriate. Data collected at Mile Point 122.05 was also found appropriate and used in the analyses for the Phase I study.

Water quality data in the FKC is limited after 2004. No data was found at Mile Point 122.05 after 2004, but some data for 2011 and 2012 was found for the FKC terminus at Calloway Avenue (see **Appendix F**). Most of the constituent values in 2011 to 2012 are similar to the values from 1957 through 2004. The TDS value from the more recent data (2011 – 2012) averages 30 mg/l versus 45 mg/l from 1957 through 2004. However, the recent data is only comprised of three samples, and the range in values (20 to 51 mg/l) falls within the range of values in the historical data (16 to 109 mg/l). Consequently, the historical data from 1957 through 2004 at Mile Post 122.05 is considered representative and was used in the analysis.

2.2 – Studied Districts

The water agencies evaluated in this study include Arvin-Edison Water Storage District, Shafter-Wasco Irrigation District, Southern San Joaquin Municipal Utility District, Delano-Earlimart Irrigation District, and Kern-Tulare Water District. These agencies are shown on **Figure 1.1**. These agencies regularly use San Joaquin River water delivered through the FKC. All of these districts have a contract for San Joaquin River Water. The Kern-Tulare Water District (KTWD) received an assignment of permanent contract rights to 5,000 AF of CVP Class II supply from South San Joaquin Municipal Utility District on March 1, 2012. This supply modification was not included in the Phase 1 analysis and has not been accounted for in this study except in a qualitative sense. This change however is believed to have a minimal impact (see Section 5 – Water and Salt Balance, for more details). However, KTWD was assumed to be able to receive Re-circulated Water in place of Friant water that they often purchase or receive via exchange from other Friant contractors. Thus, the potential impacts on KTWD of this change in source water are addressed in this report.

These districts have a combined area of about 315,500 acres (~500 square miles). They all supply agricultural or M&I water and the local farmers use various irrigation methods to grow a wide variety of crops. All of the districts use a combination of groundwater and surface water. The years of 1990 to 2002 were identified as a long-term period with nearly average water supply conditions (see Section 4 – Water and Salt Balance). Between 1990 and 2002 the districts used an average of 410,700

AF/year of CVP water, 90,400 AF/year of other surface water supplies, and 389,000 AF/year of groundwater (estimated). Refer to Table 2.2 for a summary of principal features for each district.

Table 2.2 – Summary of Studied Districts

Description	Arvin-Edison Water Storage District	Shafter-Wasco Irrigation District	Southern San Joaquin MUD	Kern-Tulare Water District	Delano-Earlimart Irrigation District
Formation Date	1942	1937	1935	1955 / 1974	1938
Gross Area (acres)	131,660	38,900	61,400	26,200	56,500
Population	19,200	29,500	52,000	2,800	8,400
Major Crops	Vineyards, oranges, potatoes, citrus, almonds, carrots	Almonds, cotton, alfalfa hay, grapes	Almonds, cotton, alfalfa hay, grapes, citrus	Citrus, grapes, nuts	Grapes, pistachios, almonds
Estimated Irrigation Efficiency	83%	75%	75%	85%	80%
Distribution System	Lined canal, Pipeline	Pipeline	Pipeline	Pipeline	Pipeline
CVP Contracts	Class 1: 40,000 AF Class 2: 311,675 AF	Class 1: 50,000 AF Class 2: 39,600 AF	Class 1: 97,000 AF Class 2: 45,000 AF	KTWD CVC: 53,300 AF Class 2: 5,000 AF	Class 1: 108,800 AF Class 2: 74,500 AF
Estimated Irrigation GW Pumping (Annual Avg)	203,000	66,400	76,300	24,100	38,000
CVP Water Deliveries (Annual Average)	95,700	54,100	102,100	38,800	120,000
Other Water Deliveries (Average Annual)	70,000	2,700	0	0	0

Notes:

1. Data taken from Analysis of *Impacts from Changed Water Sources, Groundwater Impacts*, prepared by Provost & Pritchard Engineering Group in May 2006.
2. Average annual groundwater pumping, CVP water deliveries, and other water deliveries are based on the CVP water years 1990-2002.
3. Estimated irrigation groundwater pumping includes district and privately owned wells
4. Estimated Irrigation efficiency for AEWSD is 5 year (2006 to 2010) average

3 – REGULATORY SETTING

This section discusses the significance of several water quality regulatory policies and programs and their relevance on the use of Re-circulated Water in the Friant Service Area.

USBR Water Quality Policy

The United States Bureau of Reclamation (USBR) is currently developing a 'Water Quality Policy'. The policy is expected to address all discharges to the Friant-Kern Canal and may not allow exemptions. The policy will likely address agricultural water quality standards and limits of degradation.

DWR Water Quality Policy

The Department of Water Resources is also developing a water quality policy for non-project waters that enter the California Aqueduct. The 2nd draft was released in August 2012. The acceptable water quality will be based on baseline water quality in the California Aqueduct. The draft policy includes monthly electrical conductivity values for O'Neill forebay for Wet, Near Normal, Dry and Critical years that will be used in evaluating pump-in proposals.

Water Pollution Control Act of 1948

The regulations in the federal Water Pollution Control Act of 1948 are now covered in more recent acts. In addition, the act focuses on water for human consumption, which will not be significantly impacted by the Re-circulated Water deliveries.

Clean Water Act and Safe Drinking Water Act

The federal Clean Water Act and Safe Drinking Water Act provide guidelines for water quality, with a focus on drinking water quality. The State Water Resources Control Board and Regional Water Quality Control Board have jurisdiction on drinking water quality. The Clean Water Act is important since it is the basis for the Irrigated Lands Regulatory Program (ILRP), which will require groundwater monitoring. AEWSD also banks water for Metropolitan Water District of Southern California, which is eventually extracted and delivered to them for domestic and municipal purposes.

National and California Toxics Rule

The National and California Toxics Rule focuses on chemicals entering water bodies that are toxic to humans. The Re-circulated Water will not include any constituent concentrations that are considered toxic and also will not significantly impact drinking water supplies. Note that the Rule lists salts as a contaminant, but they are not designated as 'toxic' and no suggested or mandated limits are provided.

Porter-Cologne Water Quality Control Act

The California State Porter-Cologne Water Quality Control Act describes the roles and responsibilities of the State Water Resources Control Board and the Regional Water Quality Control Boards. These roles and responsibilities may change with the CV-SALTS Program (see below). The Act does not provide limits on salt loading in soil and water, but gives the State Board the ability to enforce limitations on salt loading.

Water Quality Control Plan for the Tulare Lake Basin

The *Water Quality Control Plan for the Tulare Lake Basin Plan* (Basin Plan) provides California's administrative policies for protecting State waters. The Basin Plan states that degradation of groundwater in the Tulare Lake Basin by salts is unavoidable without a plan for removing salts from the Basin. Accordingly, the water quality objectives for groundwater salinity are directed at controlling the 'rate of increase' of salinity. The Basin Plan therefore provides acceptable rates of salinity increase for the groundwater. These were developed in 1975 and have been updated as recently as 2004. The CV-SALTS Program is developing guidelines that will be used to draft an amendment to the Basin Plan in 2014.

Table 3.1 compares the estimated annual increases in groundwater salinity (based on calculations performed for this study in Section 5 – Water and Salt Balance) versus the allowable annual salinity increases according to the Basin Plan. The Basin Plan assumes that salts are distributed throughout the entire saturated thickness of groundwater. The estimated increases in Table 3.1 also assume that the salts are distributed throughout the entire aquifer.

Table 3.1 – Estimated versus Allowable Annual Increase in Groundwater Salinity for Entire Saturated Thickness (mg/L/yr)

District	Existing Conditions[1]	Range of Estimated Increase from Re-circulated Water	Projected Annual Increase	Allowable Increase[2]
AEWSD	1.8	0.0 - 0.2	1.8 – 2.0	3.3
SWID	3.3	0.0 - 0.1	3.3 – 3.4	4.0
SSJMUD	2.1	0.0 - 0.1	2.1 – 2.2	4.0
KTWD	2.0	0.0 – 0.1	2.0 – 2.1	4.0
DEID	2.0	0.0 - 0.1	2.0 – 2.1	4.0

1 – Annual Increase in Salinity under Existing Conditions calculated during the Phase I study except for a revision in aquifer size under AEWSD.
2 – California Regional Water Quality Control Board, *Water Quality Control Plan for the Tulare Lake Basin – Second Edition*, Revised January 2004

The starting values (existing conditions) are not as important for this study as the projected annual increase in salinity.The allowable annual increase in salinity is only close to being exceeded in SWID for the "worst-case" scenario (Case 2 - Maximize

Deliveries to Friant-Kern Canal Pumpback). In conclusion, based on the salt balance calculations, the Re-circulated Water deliveries will not cause the groundwater salinity to increase at a greater rate than the allowable increases stipulated in the current Basin Plan.

State Anti-degradation Policy

The California State anti-degradation policy (SWRCB resolution 68-16) states,

> "*Whenever the existing quality of water is better than the quality established in policies as of the date on which such policies become effective, such existing high quality will be maintained until it has been demonstrated to the State that any change will be consistent with the maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water, and will not result in water quality less than that prescribed in the policies*."

The policy could feasibly be used to restrict Re-circulated Water imports to the Friant Division service area, if these imports are not considered consistent with the maximum benefit to the people of the State, which is a determination that must be made by the SWRCB. Determining compliance with this policy is subjective due to the vagueness of the guidelines. Irrigators may be subject to the anti-degradation policy under the proposed Irrigated Lands Regulatory Program, described below.

Irrigated Lands Regulatory Program

The Central Valley Regional Water Board has adopted regulatory requirements for discharges from irrigated lands (tailwater, water from underground drains, stormwater runoff) to waters of the State. The Irrigated Lands Regulatory Program (ILRP) regulates such discharges located within the jurisdiction of the Central Valley Water Board. The overall goals of the ILRP are to:

1) Restore and/or maintain the highest reasonable quality of state waters considering all the demand being placed on the water;
2) Minimize waste discharge from irrigated agricultural lands that could degrade the quality of state waters;
3) Maintain the economic viability of agriculture in California's Central Valley;
4) Ensure that irrigated agricultural discharges do not impair access by Central Valley communities and residents to safe and reliable drinking water.

The current regulatory requirements are considered part of an interim program; development of the long-term program is currently underway. Currently, the ILRP is being expanded to include a regulatory program to protect groundwater quality and will include the control of all pollutants, including salinity and nitrates. The focus of the ILRP will be on shallow groundwater. Since Re-circulated Water is on average 4 times higher and can sometimes be 10 times higher in nitrates than Friant water, its delivery could work in direct conflict with ILRP mandates. The district slated to receive the majority of

Re-circulated Water, AEWSD, already has lands designated as "High Vulnerability Areas" under the draft ILRP.

CV-SALTS Program

The Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) stakeholder driven program was created by the Central Valley Basin Regional Water Quality Control Board (RWQCB) to develop a new Basin Plan for the Central Valley groundwater basin. The program was developed to address the long-term degradation of groundwater supplies. CV-SALTS is intended to be a stakeholder driven process. The existing Basin Plan provides limits on increases of salt concentrations, and does not specifically address salt loads. The CV-SALTS Program is in process, and its final recommendations will not be released until 2014. However, it is possible the program will implement a policy on the salt load limits in a groundwater basin. With this policy, a salt "footprint" would be established, and no new salts, above historical loads, could be imported. However, agencies (and potentially) growers could trade their allowable salt loads; in other words one agency could import more salt into a groundwater basin if another reduced their salt load. This program, if implemented, could potentially be problematic for the participating districts that receive additional Re-circulated Water of the quality of SWP water.

Nitrates are another concern address by CV-SALTS. The RWQCB has a four pronged approach to the nitrate problem. It includes the ILRP, a basin-wide salinity and nitrate management problem (CV-SALTS), a groundwater quality protection strategy, and a component on dairy waste.

Groundwater Ambient Monitoring and Assessment "GAMA" program

The Groundwater Ambient Monitoring and Assessment (GAMA) Program is a California federal statewide groundwater monitoring program that began in 2000. The program has no regulatory authority, but rather collects, analyzes and archives water quality data. The data is published in public reports. GAMA literature states that local participation is voluntary and they will consult with local agencies before publishing any data. A focus of GAMA is testing for chemicals that are not normally available or are at very low concentrations. The GAMA data may eventually be used to establish baseline data, identify increases in salts over time, and identify regional trends.

Tule River Basin Study Area for Friant - Salt and Nitrate Source Pilot Implementation Study

This report, published by the CV-SALTS Program in February 2010, identifies and quantifies the significant salt and nitrate sources in the Central Valley. This information could ultimately be used to help establish a salt "footprint" for the Central Valley. The report also makes recommendations regarding land cover and soils, surface water modeling, groundwater data, groundwater flow and quality modeling, and analysis tools.

EPA's Reconsideration of "Water Transfers Rule"

Currently, water transfers, and general movement of water from one watershed to another, are exempt from National Pollution Discharge Elimination System (NPDES) permits under the Clean Water Act. In 2009, this exemption was challenged, but the United States Court of Appeals for the Eleventh Circuit upheld the exemption (*Friends of the Everglades v. So. Fla. Water Mgmt. Dist.*, No. 07-13829). However, this case may ultimately be appealed to the U.S. Supreme Court. Since the Re-circulated Water movement would involve federal water transfers, elimination of this exemption could be problematic for the participating entities if it became necessary to obtain an NPDES permit as a result.

Water Repayment Contracts and Cross Valley Canal Operating Agreement

Friant Districts each have a Water Repayment Contract with USBR, and agencies that use CVC water have a CVC Operating Agreement. These are institutional agreements as opposed to regulatory agreements. Some provisions in these agreements address the quality of water delivered. However, reviewing the legality of these agreements is beyond the scope and intent of this study.

4 – RE-CIRCULATED WATER SUPPLIES

This section documents the water supply assumptions used to identify the expected timing and volume of Re-circulated Water delivered to the five study districts. Three water delivery scenarios are identified that are used to evaluate potential impacts to the districts. Below are specific discussions on the possible timing and volume of surface water supplies, and the specific scenarios that were evaluated. The primary references used to develop the water supply assumptions include:

1. Friant-Kern Canal Reverse Flow Pump-Back Facilities – Water Supply Analysis Details, USBR (2010). Presentation materials on the results of modeling to determine how much Re-circulated Water could be delivered to impacted districts considering conveyance capacity (California Aqueduct and Cross Valley Canal), San Luis Reservoir Storage capacity, and proposed reverse pumping capacities in the Friant-Kern Canal. A copy of this presentation is included as **Appendix C**.
2. Table of Water Supply Impacts - FWA. Table of estimated water supply impacts and mitigation water deliveries to each agency directly impacted by the San Joaquin River Restoration Settlement provided by FWA dated May 7, 2009. These tables are included as **Appendix D**.

4.1 - General Assumptions

The following general assumptions were used to estimate possible Re-circulated Water deliveries:

1. East/West exchanges that move water from San Luis Reservoir to Millerton Lake, when applied, would reduce the amount of recirculation water conveyed in the Aqueduct. This study assumes such East/West exchanges would not occur.
2. All Friant-Kern Canal pumpback facilities are in-place. Pumpback facility capacities include: 500 cfs at the Kern (CVC/FKC Intertie), Shafter-Wasco and Poso Creek Checks, and 300 cfs at the Reservoir Check (Lake Woolomes). Instantaneous Re-circulated Water deliveries are not possible to SWID, KTWD, SSJMUD and DEID if the FKC is in forward flow mode delivering water to AEWSD.
3. The five Districts combined have sufficient demand for all Re-circulated Water and their share of the San Joaquin River Restoration Program's "16(b)" water (i.e. $10 RWA water) and "Title 3" (now "Part 3") water (i.e. groundwater banks). These later two are mitigation water supplies intended to partially compensate districts that are impacted by the Settlement. Fully utilizing these supplies will lessen the overall water supply impacts to the studied districts.
4. No land is fallowed as a result of water supply reductions. Any water shortages resulting from the Settlement will be made up with increased groundwater pumping. It is recognized that these increases in groundwater pumping may not

be sustainable in the long-term. This assumption will likely lead to groundwater overdraft in each studied district.

4.2 - Surface Water Supplies

Table 4.1 shows how surface water deliveries are expected to be impacted by the Settlement. These values were obtained from FWA (2009). Negative numbers indicate a reduction in the type of water supply.

Table 4.1 – Annual Impacts to Surface Water Deliveries Resulting from the San Joaquin River Settlement (thousand acre-feet)

District	Class 1 & 2 Deliveries	Class 2/Sec 215 Deliveries	Re-circulated Water[1]	16(b) and P3 Water[2]	Net Water Loss
AEWSD	-30.3	-9.5	8.7	20.0	-11.2
SWID	-6.5	-1.2	2.0	3.7	-2.1
SSJMUD	-10.4	-1.5	3.3	5.5	-3.1
DEID	-13.3	-2.3	4.1	7.3	-4.1
KTWD	-	-	-	-	-
Total	**-60.5**	**-14.5**	**18.1**	**36.5**	**-20.5**

1 – Deliveries are apportioned based on each district's allocated share of impacts
2 – 16(b) is Restoration Water Account (RWA) water that allows impacted Friant contractors to mitigate their impacts by being able to buy floodwater at $10/AF to the extent they have been impacted. P3 water (Part 3 formerly Title 3 or T3 water) is water generated out of the facilities and programs built to increase groundwater recharge and recovery using the $50 million authorized as part of Title III of the San Joaquin River Restoration Act. The allocations in Table 4.1 assume that funding is split based on the share of impacts experienced by each Friant contractor.

Table 4.1 incorporates the following assumptions:

1. Values represent annual averages.
2. It is assumed that KTWD, as a CVC contractor, will not be directly impacted by the Restoration Program.
3. Re-circulated Water values in Table 4.1 differ from those simulated in the Friant-Kern Canal Pumpback Study (USBR, 2010). The values above are smaller because it was assumed that some Re-circulated Water is delivered to other Friant Division districts. If the districts in Table 4.1 receive more Re-circulated Water than shown above, which is likely, they will have an equivalent amount of Class 1 or Class 2 water not delivered. The values in Table 4.1 are important because they show: 1) deliveries apportioned based on each district's share of impacts, which is the basis for one of the cases (Case 3) that is later evaluated; and 2) Net Water Loss, which is important for performing a water and salt balance (see Section 5).

Deliveries Above the Poso and Reservoir Check Structure

Simulations prepared by USBR (2010) and USBR (Oct. 2010) provide Re-circulated Water volumes above the Poso Check Structure and Reservoir (Lake Woolomes) Check Structure, but do not state which districts use the water. As a result, the following assumptions were made:

1. Water delivered between the Poso Check and Reservoir Check is used exclusively by SSJMUD; and
2. Water delivered above the Reservoir Check is proportioned between DEID and KTWD based on the ratio of their historical deliveries from the Friant-Kern Canal.

Table 4.2 shows the historical water deliveries for DEID and KTWD between 1990 and 2002, which was determined to represent the average long-term hydrology.

Table 4.2 – Historic Water Deliveries Above the Reservoir Check

District	Average Annual Deliveries (AF)	Ratio
DEID	120,000	72%
KTWD	47,700	28%
Total	**167,600**	**100%**

4.3 - Water Supply Scenarios

The analysis includes three scenarios for the apportioned delivery of Re-circulated Water with the assumptions regarding the changes in deliveries directly from Millerton Lake remaining the same between the alternatives, as follows:

Case 1: Maximize Re-circulated Water deliveries directly to AEWSD.

Case 2: Maximize Re-circulated Water deliveries to Friant-Kern Canal for pumpback operations.

Case 3: Apportion deliveries based on every Friant Division district's share of the Re-circulated Water consistent with each district's water supply impacts from providing Restoration flows. This scenario is theoretical, because the Re-circulated Water cannot physically be delivered to all districts that provide restoration flows but does address the impacts to the study districts from their proportionate share of impacts anticipated with the SJR Settlement.

These scenarios are discussed below. The scenarios are based on average-annual Re-circulated Water deliveries which are estimated to be 58,400 AF/year. Actual deliveries are expected to range from 0 to about 250,000 AF/year.

The Friant-Kern Canal can store 2,572 AF between the White River Check and Kern River Check (canal terminus) when water is at the normal operating level (source:

FWUA Information Report on the Friant-Kern Canal). When the canal is returned to forward flow conditions, the remaining Re-circulated Water in the canal will also begin to flow forward. Depending on instantaneous demands from the districts along the FKC canal, the studied districts could receive varying amounts of Re-circulated Water still present in the FKC. The opposite condition would exist for districts along the FKC (except AEWSD) when reverse flow operations are initiated, whereby the lower end of the Friant-Kern Canal is full of Millerton Lake/San Joaquin River water which gets mixed with incoming Re-circulated Water. The cases described below assume that this condition does not influence water deliveries to individual districts. However, it should be recognized that some of the studied districts, in particular AEWSD, could actually receive more water Re-circulated Water and the four remaining study districts receive less Re-circulated Water under this reverse flow scenario depending upon instantaneous demands at the time of switching to and from reverse flow operations on the FKC.

Case 1: Maximize Deliveries to AEWSD

This case represents operations that maximize Re-circulated Water deliveries to AEWSD. Under this scenario, Re-circulated Water is only delivered to the FKC for pumpback operations once AEWSD can no longer take this water, based on their demand or conveyance capacity limitations. All water delivered to AEWSD is directly delivered through the CVC, and it is assumed that AEWSD does not experience any residual impact from the changeover from SWP to FKC water. The values were derived using data provided by USBR (2010). Expected annual average deliveries are shown in Table 4.3.

Table 4.3 – Case 1: Maximize Re-circulated Water Deliveries Directly to AEWSD

District	Annual Deliveries (AF)
AEWSD	34,600
SWID	6,800
SSJMUD	6,600
DEID	3,100
KTWD	1,300
“Surplus”	6,000
Total	**58,400**

USBR (2010) concluded that Re-circulated Water deliveries would include 6,000 AF of “Surplus Water.” USBR (2010) assumed that this water is not delivered to any of the districts since it is not readily apparent who would have the capability of using this water due to its timing and lack of ability to be reregulated. Consequently, it was decided early in this study not to assign the Surplus Water to any one study district.

Case 2: Maximize Deliveries to Friant-Kern Canal Pumpback

This alternative would maximize Re-circulated Water deliveries to the FKC for pumpback operations while minimizing Re-circulated Water deliveries to AEWSD. This would be accomplished by delivering Re-circulated Water to the FKC for pumpback operations when AEWSD can meet all or most of their demands with other supplies including but not limited to groundwater and/or Kern River water. The values in Table 4.4 below were derived using data from USBR (2010).

Table 4.4 – Case 2: Maximize Re-circulated Water Deliveries to Friant-Kern Canal

District	Annual Deliveries (AF)
AEWSD	26,100
SWID	8,500
SSJMUD	10,200
DEID	5,300
KTWD	2,100
"Surplus"	6,200
Total	**58,400**

Table 4.4 incorporates the following assumptions:

1. Water delivered to AEWSD is by direct delivery from the Cross Valley Canal.
2. "Surplus Waters," which are 11 percent of total water supplies, or 6,200 AF, and, similar to Case 1, are not assumed to be delivered to any one study district. Consequently, not all of the potential Re-circulated Water is assumed to be used by the studied districts.
3. The USBR (2010) simulation included a total of 57,300 AF of water which differs slightly from the 58,400 used in Case 1. To be consistent, and provide similar quantities for comparing impacts, each value was proportioned up in Table 4.4 so that the total equals 58,400 AF for both Cases 1 and 2.

Case 3: Apportion Deliveries Based on Districts' Allocated Share of Impacts

This scenario attempts to distribute Re-circulated Water based on each district's share of the water supply impacts of providing Restoration Flows. This ostensibly represents the amount of Re-circulated Water that each Friant Division contractor should have expected to have to "deal with" in one way or another as a result of Settlement/Restoration Flows and receiving their proportionate share of those flows back as Re-circulated Water. This is also the same amount of water that is shown in Table 4.1 as Re-circulated Water (column 4). There are no limitations placed on the volumes delivered to reflect existing or planned delivery facilities. Physically it would be difficult to deliver all Friant Division districts their apportioned share of the Re-circulated Water.

Table 4.5 shows the estimated deliveries based on allocated share of impacts.

Table 4.5 – Case 3: Deliveries Apportioned Based on Allocated Share of Re-Circulated Water

District	Recaptured Water (AF)
AEWSD	8,700
SWID	2,000
SSJMUD	3,300
DEID	4,100
KTWD	-
Subtotal	**18,100**
Other Friant Contractors	40,300
Total	**58,400**

Appendix D includes the proportionate share of deliveries for all 28 Friant contractors, as well as estimated increases in salt importation, which are discussed in Section 5.

4.4 - Summary

Following is a summary of the anticipated Re-circulated Water deliveries for the three water supply cases. The following table also compares the expected re-circulated water deliveries to average annual CVP water deliveries for each district.

Table 4.6 – Summary of Recaptured/Re-circulated Water Deliveries for Three Scenarios

District	Annual CVP Water Use (AF)[a]	Average Annual Deliveries (AF)			Distribution of Re-circulated Water Deliveries (percentage)		
		Case 1[b]	Case 2[c]	Case 3[d]	Case 1[b]	Case 2[c]	Case 3[d]
AEWSD	95,700	34,600	26,100	8,700	59%	45%	48%
SWID	54,100	6,800	8,500	2,000	12%	15%	11%
SSJMUD	102,100	6,600	10,200	3,300	11%	17%	18%
DEID	120,000	3,100	5,300	4,100	5%	9%	23%
KTWD	38,800	1,300	2,100	-	2%	4%	-
"Surplus"	-	6,000	6,200	-	10%	11%	-
Total	**410,700**	**58,400**	**58,400**	**18,100**	**100%**	**100%**	**100%**

Notes:
a - Average annual CVP SJR water used during 1990-2002
b - Case 1:– Maximize deliveries directly to AEWSD
c - Case 2: Maximize deliveries to Friant-Kern Canal
d - Case 3: Deliveries apportioned based on allocated share of Re-circulated Water

5 – WATER AND SALT BALANCE

The purpose of the water and salt balance was to estimate the total volume of salts that would be imported with the Re-circulated Water and its long-term impacts on groundwater levels and quality. The water and salt balance calculations from the Phase I Study were revised according to anticipated changes in CVP SJR water and SWP/Delta water supplies resulting from the three Re-circulation Water scenarios.

5.1 - Previous Analysis

The Phase I Study included development of a detailed water balance and salt balance model for evaluating the impacts of importing SWP water into the Friant Division service area. Specific work performed in the Phase I study included:

1. Perform detailed water balance calculations for each studied district to estimate the volumes of different water sources that impact the local groundwater quality.
2. Evaluate the studied district's hydrogeologic conditions to assist with determining aquifer characteristics, groundwater flows, and possible changes in groundwater salinity.
3. Identify typical water quality characteristics of each water source and estimate potential changes in groundwater salinity from a change in source waters.
4. Predict long-term impacts on groundwater quality for each studied district under varying water supply scenarios.

The goals of this Re-circulated Water study are essentially the same as Phase I, except that different volumes of Delta originated water were analyzed in the water and salt balance. Refer to the Phase I Study (Provost & Pritchard, 2006b, Section 4) for details on the methodology and assumptions used in the analyses.

5.2 - Water Balance

A detailed hydrologic mass balance (water balance) was performed for each studied district. The water balance was used to establish existing conditions so impacts on groundwater levels and quality from anticipated deliveries of Re-circulated Water could be predicted.

To establish average conditions for the water balance, and ultimately the salt balance calculations, average hydrologic conditions were determined for a multi-year study period considered to represent the average long-term hydrology. The study period was selected as CVP water years (March to February) for 1990-2002. This period was used in the Phase I Study and, when averaged, is considered to represent a "normal" or "typical" period for each of the districts. In other words, this period was determined statistically to have the best correlation to average long-term San Joaquin River flow into Millerton Reservoir. Projected conditions for this study assume that the selected period of hydrology mirrors the historical average and represents future conditions. Criteria for selecting this period included:

1. Equivalence to long-term mean water supply;
2. Sufficiently long period to establish average water conditions;
3. Inclusion of both wet and dry periods;
4. Availability of data;
5. Proximity to present time;
6. Reflection of current cultural and water management practices; and
7. Reflection of capacity of facilities.

In order to check the water balance in the Phase I Study, the change in groundwater storage was calculated using two distinct methods: 1) Difference in the inputs and outputs to the groundwater using data from the water balance; and 2) Based on changes in groundwater levels using specific yield values. A comparison of values obtained from these two methods helped to validate the results of the water balance.

Changes to Water Balance

The following changes were made to the water balance models developed for the Phase I Study:

1. CVP SJR water deliveries were reduced based on anticipated curtailments for the San Joaquin River Restoration Program.
2. Anticipated Re-circulated Water deliveries (Delta water) were added based on the three cases presented in Chapter 4.
3. RWA/$10 water/16(b) and Title 3 water deliveries (mitigation waters as part of Settlement) were added as CVP water supplies.
4. Municipal and industrial groundwater pumping volumes were recalculated using a revised landscape irrigation efficiency (this change was made based on comments from peer review experts on the Phase I Study, see **Appendix E**).
5. Groundwater pumping was increased to account for overall reductions in water supplies while holding demand steady to current practices. The negative impact on groundwater levels from the additional pumping was estimated. Reduced surface water supplies would also result in less groundwater recharge in some years.

The increased groundwater pumping may impact groundwater flow patterns, including groundwater inflow and outflow in each district. However, it was agreed at the beginning of the study that the groundwater flows estimated in the Phase I Study would be used, due to the extensive time and difficulty in predicting groundwater contours under the new hydrologic conditions. The water balance is based on historical groundwater flows from 1990-2002, and these are considered a reasonable approximation of potential future conditions.

The Kern-Tulare Water District acquired, via an assignment, a permanent contractual right to 5,000 AF of CVP Class 2 water from SSJMUD on March 1, 2012. This supply was not considered in the Phase 1 Study and this analysis was not revised to include this supply since the impact is believed to be minimal. Based on data provided by FWA, SSJMUD can expect to lose about 9 percent of their Class 2 allocation each year to the river restoration. Assuming similar impacts to KTWD, this would equate to 5,000 AF x 9 percent = 450 AF. About 27 percent of this would be redelivered as Re-circulated Water, or 27 percent x 450 AF = 122 AF. The impact from importing an additional 122 AF of Re-circulated Water would be minimal and was therefore not evaluated. In addition, the overall impact to the studied districts as a whole would be the same; the impact would just be shifted from SSJMUD to KTWD.

5.3 - Salt Balance

A salt balance is similar to a water balance in that the salinity change in groundwater can be approximated by adding up all the salt inputs and subtracting the salt outputs. Two salt balance analyses were performed including one that evaluated impacts to the entire saturated thickness of the groundwater, and another salt balance focused on the shallow groundwater mixing-zone, since the majority of salts from deep percolation of applied surface water accumulate in the upper portion of the groundwater.

The purpose of the salt balance calculations is to provide a comparative analysis of likely impacts to groundwater. It is expected that the total dissolved solids concentration in the groundwater will change over time, since additional salt is being brought into the basin with each type of water. However, the exact impact on groundwater is difficult to predict because of the lag time in salts reaching the groundwater, the historical lack of routine groundwater quality monitoring in many districts, and unknown rates of downward groundwater flow below the water table. With this in mind, the salt balance calculations were simplified so they could be readily understood and could be repeated for each district. For instance, the salt balance calculations assume that the additional salts imported with the Re-circulated Water would instantaneously move through the soil profile and mix with the groundwater, whereas, in reality, it will take a number of years, even decades, for the salts to eventually reach the groundwater.

Appendix E includes a list of hydrogeologic assumptions for each impacted District that were used in the salt balance. These assumptions were taken from the Phase I study and cover topics such as depth to confined aquifer, total aquifer volume, etc. The aquifer volumes presented in the Phase I study for AEWSD were changed for this study. In AEWSD it was assumed that re-circulated water only mixes with the aquifer covering 90,000 acres of the 132,000 total district area. This impacted area is generally the area that receives surface water, and a simplified hydrogeologic analysis suggests that deep percolation would generally stay in these areas. A map showing the area assumed to be impacted is included in **Appendix E**. This changed the study results since re-circulated water mixed with a smaller aquifer volume, leading to higher annual increases in salinity. In all the other districts it was assumed that re-circulated water

mixes through the entire aquifer, since surface water is delivered to almost their entire service areas. Even with the inaccuracies created by using these simplifying assumptions, the salt balance calculations yield useful information to compare the potential affects from using Re-circulated Water in the studied districts.

Baseline salinity conditions were determined for each District in the Phase I study. These included average aquifer salinity and annual increase in salinity in mg/l. The Phase I study estimated current salinity increases of 1.2 mg/l and 3.3 mg/l in AEWSD and SWID, respectively. The increase in AEWSD was changed to 1.8 mg/l/year in this study since the impacted area and aquifer volume were reduced, as described above. SSJUMD, DEID and KTWD were each estimated to be about 2.0 mg/l. The reason for the differences cannot be easily explained, as numerous variables played into the salt balance results. However, one of the major reasons for the low AEWSD value is the large percentage of water demands met with groundwater in AEWSD compared to other districts. In the salt balance model, groundwater usage does not increase salinity, since it assumes that the salts are just re-circulated. In SWID, the total saturated aquifer thickness is 755 feet, which is lower than other districts, such as AEWSD and SSJMUD, where it is 1,000 feet. Therefore in SWID there is less aquifer volume for the salts to mix in resulting in a higher annual increase.

The salt balance estimates made in the Phase I Study matched closely with monitored groundwater salinity changes in AEWSD (Provost & Pritchard, 2006b). This indicates that the salt balance used in the Phase I study and this study have some facial validity. Extensive groundwater monitoring records were not available for comparison in the other studied districts. Each of the other districts has unique characteristics that may influence the accuracy of the simulations. Nevertheless, the results obtained for AEWSD would suggest that the salt balance method should provide reasonable results for the other districts.

Some growers in the Friant service area apply gypsum to help increase soil infiltration potential. Theoretically, less gypsum should be needed when Re-circulated Water is used because it has higher salt content. This topic was investigated in the Phase I Study with further analysis in this study. It was assumed that growers would not modify their gypsum application when receiving Re-circulated Water. Refer to **Appendix B** – Peer Review Comments for further discussions and justification for this assumption.

5.4 - Results

The results of the water and salt balances are provided in **Appendix E.** The salt balance results are summarized in Table 5.1.

Table 5.1 - Summary of Salt Balance Calculations

	AEWSD	SWID	SSJMUD	KTWD	DEID
Anticipated annual impacts to groundwater aquifer - mg/l/yr (entire saturated thickness)					
Existing conditions					
Increase in GW salinity	1.8	3.3	2.1	2.0	2.0
Case 1 : Maximize Deliveries to AEWSD					
Resulting Increase in GW salinity	2.0	3.4	2.2	2.1	2.0
Additional salinity with re-circulated water deliveries	0.2	0.1	0.1	0.1	0.0
Case 2: Maximize Deliveries to Friant-Kern Canal					
Resulting Increase in GW salinity	2.0	3.4	2.2	2.1	2.1
Additional salinity with re-circulated water deliveries	0.2	0.1	0.1	0.1	0.1
Case 3: Deliveries Based on Allocated Share of Impacts					
Resulting Increase in GW salinity	1.8	3.3	2.1	2.0	2.1
Additional salinity with re-circulated water deliveries	0.0	0.0	0.0	0.0	0.1
Anticipated annual impacts to groundwater aquifer - mg/l/yr (shallow groundwater)					
Existing conditions					
Increase in GW salinity	9.1	8.2	7.1	3.6	4.4
Case 1 : Maximize Deliveries to AEWSD					
Resulting Increase in GW salinity	10.2	8.6	7.4	3.7	4.5
Additional salinity with re-circulated water deliveries	1.1	0.4	0.3	0.1	0.1
Case 2: Maximize Deliveries to Friant-Kern Canal					
Resulting Increase in GW salinity	10.0	8.6	7.5	3.8	4.5
Additional salinity with re-circulated water deliveries	0.9	0.4	0.4	0.2	0.1
Case 3: Deliveries Based on Allocated Share of Impacts					
Resulting Increase in GW salinity	9.6	8.3	7.3	3.6	4.5
Additional salinity with re-circulated water deliveries	0.5	0.1	0.2	0.0	0.1
Predicted Groundwater Quality after 30 Years - mg/l (entire saturated thickness)					
Starting irrigation groundwater quality	430	370	490	400	330
Continue existing conditions (predicted after 30 years)	484	469	552	461	390
Case 1 : Maximize Deliveries to AEWSD	490	472	555	463	390
Case 2: Maximize Deliveries to Friant-Kern Canal	490	472	556	464	393
Case 3: Deliveries Based on Allocated Share of Impacts	484	469	553	461	393
Predicted Groundwater Quality after 30 Years - mg/l (shallow groundwater)					
Starting irrigation groundwater quality	700	570	800	700	490
Continue existing conditions (predicted after 30 years)	973	816	1,013	808	622
Case 1 : Maximize Deliveries to AEWSD	1,006	828	1,021	812	625
Case 2: Maximize Deliveries to Friant-Kern Canal	1,000	828	1,024	814	625
Case 3: Deliveries Based on Allocated Share of Impacts	988	819	1,018	809	625
Additional Salts Imported (tons/year)					
Case 1 : Maximize Deliveries to AEWSD	9,210	1,820	1,700	370	640
Case 2: Maximize Deliveries to Friant-Kern Canal	6,780	2,310	2,730	600	1,260
Case 3: Deliveries Based on Allocated Share of Impacts	1,810	450	750	0	910
Impact to Groundwater Levels (feet/year)					
Case 1 : Maximize Deliveries to AEWSD	-1.0	-0.6	-0.3	0.0	-0.9
Case 2: Maximize Deliveries to Friant-Kern Canal	-1.0	-0.6	-0.3	0.0	-0.9
Case 3: Deliveries Based on Allocated Share of Impacts	-1.0	-0.6	-0.3	0.0	-0.9

The following conclusions can be drawn from the water and salt balance analyses:

Comparison of the Cases. Case 3 represents the impacts the districts should expect if Re-circulated Water was distributed on an equitable basis relative to their respective "share" amongst all of the districts that are supplying water to the San Joaquin River Restoration Program. However, the districts evaluated in this study can expect to receive more Re-circulated Water because of facility restrictions that prevent, or make it difficult, to deliver Re-circulated Water to other geographical areas within the Friant

Division service area. The groundwater levels will not be impacted by delivering more Re-circulated Water to the studied districts since they would likely replace an equal volume of CVP SJR water when Re-circulated Water volumes are increased. Case 1 and 2 will result in a larger volume of imported salts and a greater increase in groundwater salinity than Case 3.

Groundwater Salinity. Increases in salinity (mg/L) in the shallow aquifer are estimated to range from 0.1 to 1.1 mg/l/year for Cases 1 and 2 (the most likely scenarios). Salinity increases are lower when they are assumed to be distributed over the entire aquifer thickness, however, the salts will likely accumulate in the shallow aquifer.

Salt Importation. New salts will be imported with the Re-circulated Water. It is estimated that about 13,700 tons/year of new salts will be imported under Case 1 and 2 into the studied districts (note that this value also considers a reduction in salt imports due to reduced San Joaquin River CVP diversions). Case 3 would result in about 4,000 tons/year of additional imported salts to the five study districts. **Appendix E** includes a table showing the additional salts that would be imported for ranges in the salinity differences of SWP and FKC water. The long-term average difference is 210 mg/l, but it can vary different times of the year. For instance, under long-term average conditions, the table shows that 2,856 tons of additional salt will be imported for a range of water volumes imported.

Impacts to Groundwater Levels. Groundwater levels, even with the mitigation waters (Re-circulated, 16(b), and P3 waters), are anticipated to decline with average annual losses estimated to range from 0.3 feet/year in SSJMUD to 1.0 feet/year in AEWSD. KTWD will not experience groundwater level declines as a result of this program since they are assumed to not have a Friant CVP contract and will not directly experience water curtailments. The groundwater level declines will be the same for all three cases analyzed, since the districts will receive the same overall quantity of water in each case; only the mix of Re-circulated Water and CVP SJR water would vary.

6 – AGRONOMIC IMPACTS

This section describes potential impacts to crop yields, on-farm irrigation systems, soil physical characteristics, soil amendment practices, and leaching requirements as a result of importing Re-circulated Water into the study area. These topics were initially evaluated by Provost & Pritchard (2006c), with assistance from Dellavalle Laboratory, an agronomic consulting firm, during the Phase I Study that anticipated a larger exchange of Delta originated water. The agronomic impact analysis from the Phase I Study was revised for this study according to anticipated changes in CVP SJR and Delta water supplies as a result of the Re-circulated Water with its assumed SWP water quality.

Historic water quality tests and farmers' experience show San Joaquin River (SJR) water from Millerton Lake to have consistently high quality for irrigating even the most sensitive crops. The primary agronomic concern with SJR water is that it's extremely low salt content can cause or exacerbate infiltration problems, which farmers in the Friant Division service area often combat by applying gypsum, manure, and/or green waste.

Historic water quality tests and farmers' experience (in areas that receive SWP water) show SWP water quality to be adequate for irrigation of virtually all crops even though the concentration of most constituents is higher than SJR water. Concentrations of specific constituents can occasionally, although rarely, reach levels of potential concern for some sensitive crops if irrigated with SWP water under certain conditions (i.e., potential for leaf burn).

Again, for the sake of trying to use consistent terminology, in the following sections 'SWP quality water' is used when referring to historical SWP water quality including Re-circulated Water that would be delivered through the California Aqueduct and CVC to the studied districts. The term 'San Joaquin River water' or 'CVP SJR water' refers to San Joaquin River water directly diverted from Millerton Lake and delivered through the Friant-Kern Canal to the studied districts.

6.1 - Re-circulated Water Quality Variability

The Re-circulated Water program would increase the volume of higher salinity Delta water delivered to the Friant service area. Re-circulated Water is assumed to be the same quality as SWP (and Westside CVP) water pumped from the Delta, which differs from SJR/Millerton Lake water in several constituents that potentially could impact agronomic practices. The anticipated blend of SJR water and Re-circulated Water that would be delivered at any specific time to a Friant Division district is unknown. Consequently, this analysis assumes that all irrigation occurs with Re-circulated Water, thus providing an upper end or worst case of potential impacts.. Because the Re-circulated Water program will only operate for a portion of the irrigation season, the

potential impacts are anticipated to actually be less than predicted because there will be a blending of SJR and Re-circulated water use during the irrigation season.

To evaluate potential agronomic impacts, it is important to consider the maximum constituent values rather than just the average Delta water quality. Accordingly, this analysis considers the maximum values. Based on monthly grab samples collected by DWR, the variability between Delta water minimum, maximum and average constituent values is indicated in **Table 6.1**.

Table 6.1 – Comparison of SWP Water Quality

	Alkalinity (as CaCO3 mg/l)	Boron (mg/l)	Calcium (mg/l)	Chloride (mg/l)	Electrical Conductivity	Hardness (as CaCO3 mg/l)	Magnesium (mg/l)	Nitrate (mg/l)	pH	Sodium (mg/l)	Sulfate (mg/l)	TDS (mg/l)	Bicarbonate (calc'd)	SAR (calc'd)
1980 - 2011														
Maximum	106	0.9	84	179	1,030	354	35	10.0	9.0	138	364	722	175	5.8
Minimum	34	0.1	10	3	129	40	3	0.0	5.5	11	8	90	43	0.8
Average	72	0.2	21	72	492	107	13	2.5	7.7	55	51	283	88	2.3
1994-2003														
Maximum	106	0.6	84	133	1,030	354	35	8.8	8.4	99	364	722	175	5.8
Minimum	41	0.1	13	27	237	57	6	0.2	6.9	22	20	139	50	1.2
Average	72	0.2	21	59	436	101	12	2.2	7.7	46	47	251	85	2.0
2002 - 2011														
Maximum	95	0.3	30	133	726	158	21	7.2	9.0	88	72	408	136	3.3
Minimum	40	0.1	11	18	190	50	5	0.3	5.5	17	15	107	49	1.1
Average	73	0.2	19	69	449	99	12	2.8	7.6	49	37	256	84	2.1

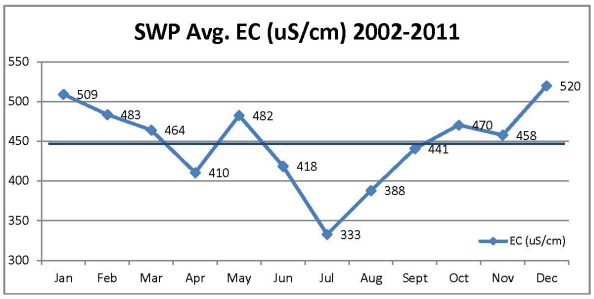
SWP water quality data from 1994-2003 was used for analysis of impacts in Phase 1 FWUA/MWDSC Study
SWP water quality data from 2002-2011 was used for analysis of impacts of recirculated water

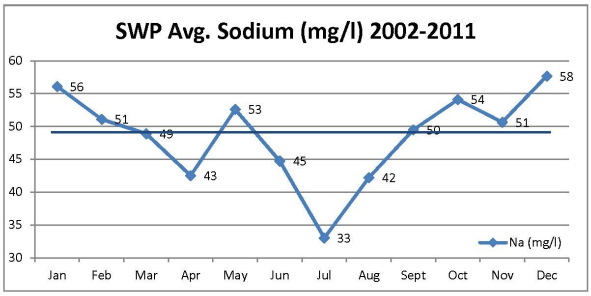
Table 6.1 compares the measured SWP water quality values from several periods. The period 1980-2011 is a 32-year long-term average that covers multiple water year types and changes in Delta operations. A copy of the SWP water quality data for the years 1980-2011 is contained in Appendix F. SWP water quality data from 1994-2003 was used for analysis of impacts in the Phase I Study and is only included herein for comparison purposes. SWP water quality data from 2002-2011 is the most recent 10-year period available after implementation of the Bay-Delta Accord and is considered representative for current and future conditions for pumping out of the Delta and as such, was used for this analysis of potential impacts resulting from the use of Re-circulated Water. The Sodium Absorption Ratio (SAR), which indicates the relative activity of sodium ions as they react with clay particles, was calculated for each data point during the period.

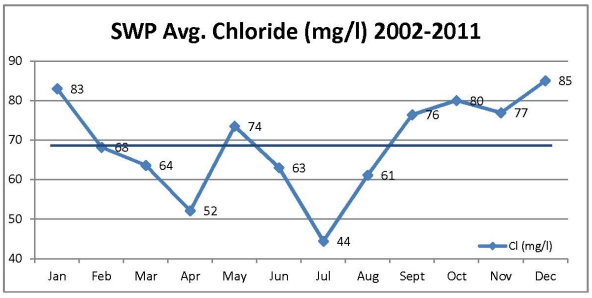
It is interesting to note that while the average water quality is very similar between the periods shown in Table 6.1, the maximum values measured in the monthly grab samples during the 2002-2011 period were lower and the minimum values were higher than during the other periods that included data prior to 2002. In fact, nearly all of the highest maximum values were measured in the 1980's to mid-90's (as shown in the data contained in Appendix F), and it appears that many of the higher maximum values can be attributed to a single event in 1995 which may have involved floodwater entering the California Aqueduct. Occasionally, some values appear to be suspect because they are outside the historical norm. For instance, in May 1983, the boron concentration was measured at 0.9 mg/l, while the prior and following month were 0.4 mg/l and 0.1 mg/l respectively. The next highest boron level in 32 years of record is 0.6 mg/l, which for practical purposes can be considered the maximum boron level rather than 0.9 mg/l.

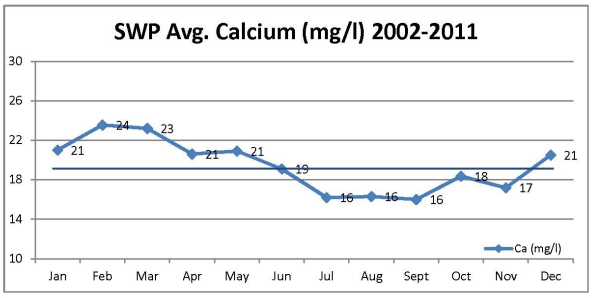
The quality of the SWP water varies throughout the year, with the best average water quality occurring in the summer months. Most restoration water releases are anticipated to occur in the spring, but it is still unknown when most re-circulated water would be delivered to the Districts. Some water could be delivered within a few weeks of being released, but it could also be stored in the Delta or San Luis Reservoir and released when convenient to the Department of Water Resources and project operations. **Figure 6.1** indicates the monthly variability of average SWP water quality for several key constituents.

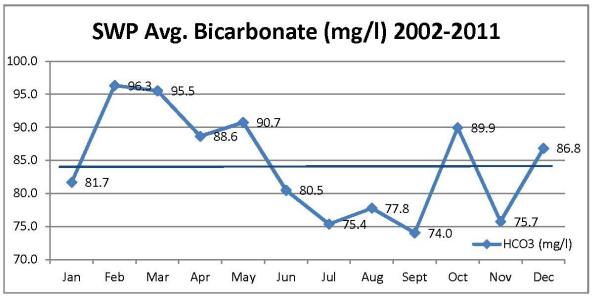
Figure 6.1 - Monthly Variability of Average SWP Water Quality

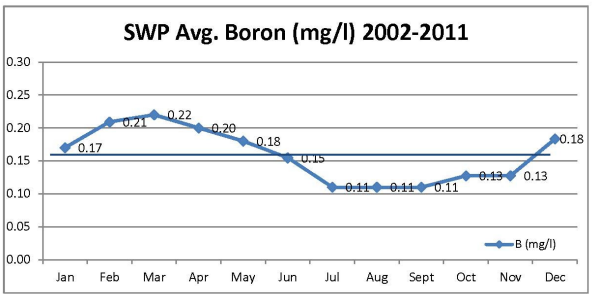


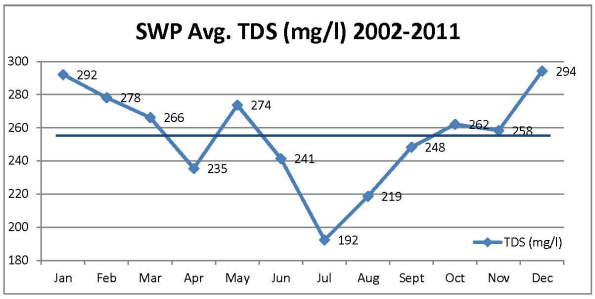












The graphs of Figure 6.1 indicate that the best SWP water quality occurs during the summer months, when the greatest amount of irrigation is generally occurring and delivery of the Re-circulation Water is likely to occur. This would help to minimize potential water quality impacts from the receipt of Re-circulated Water in lieu of CVP SJR supplies. Periodic grab samples of SWP water are collected for analysis of trace elements, and a review of the available SWP water quality data indicates that trace

element concentrations are below the recommended maximum concentrations, indicating that trace elements are not a concern.

6.2 – Crop Yield Potential Impacts

Since the SWP water has a higher mineral content than Friant water, there are some potential impacts to crop yields. It should be noted that actual impacts of a water quality differential may vary greatly from location to location depending upon a wide variety of site specific factors including, but not limited to: blending of water sources, timing of re-circulation, USBR allocations, weather related factors, soil differences, crop type and management, cultural practices, types of irrigation systems, management practices (including soil amendments), surface drainage, and subsurface conditions including adequacy of drainage. Analysis of impacts can only be made in general based upon typical expected responses, thus the term "relative impact" should be used. The primary concerns regarding potential crop yield impacts from receiving water of different quality pertains to salinity, specific ion impacts, and other miscellaneous impacts.

Irrigation water salinity affects on crop yields vary greatly from crop to crop, and depend upon many different factors, such as crop variety and rootstock, soil type, climate, water quality, timing, irrigation method and management factors. The presence of excessive amounts of salts, or salinity, in irrigation water will affect crop water availability, and thus yield. Salinity affects the ability of plants to extract water from soil. Increased salinity in irrigation water increases the osmotic potential in the root zone and can lead to a reduction in yield because plants are unable to extract sufficient moisture from the soil to meet evaporative demands. Generalized relationships between irrigation water salinity (as measured by Electrical Conductivity, or EC) and crop yield reduction have been developed by researchers at various universities, based upon carefully controlled bench-scale trials. Plant response is based on soil salinity (EC_e) resulting from sustained irrigation with water having a constant and specific water salinity (EC_w), under specific conditions. These relationships are based upon university research and are the best available and most commonly used "tools" agronomists employ to assess potential yield impacts resulting from irrigation water salinity. High salt levels can also inhibit plant germination and emergence, which is the most salt-sensitive growth period for most crops.

In addition to the effects of salinity, some crops can be injured by excessive levels of certain specific ions. This effect is called "specific ion toxicity". The primary constituents in irrigation waters that can cause specific ion toxicity include sodium (Na), chloride (Cl), and boron (B). Sprinkler irrigated fruit and vegetable crops would be the most sensitive to chloride and sodium levels because of potential foliar absorption and associated leaf burn.

Undiluted SWP water will occasionally have specific ion concentrations and total salinity that crosses into the area of "slight to moderate" restriction on use, but the tolerance thresholds developed by university researchers assume irrigation water of that quality is

applied for all irrigations. In all likelihood, the maximum concentrations in SWP water would not be sustained for long periods of time during delivery of the Re-circulated Water, and the average quality of SWP water is below the thresholds where foliar toxicity would be expected to occur for even the most sensitive of crops. It should be noted, however, that foliar injury could potentially occur from even short term exposure to excessive levels, which is more acute with sprinkler irrigation.

Sprinkler irrigated fresh fruits and vegetables could also be susceptible to “white wash”, and reduced marketability if bicarbonate concentrations in SWP water were too high and similar concentrations of soluble calcium were also found in the water. Bicarbonate concentrations in SWP water theoretically could cause “white washing” under sprinkler irrigation, especially under dry and breezy conditions, where a white residue is left on the surface of leaves or vegetables causing a cosmetic problem. “White washing” has been seen by growers occasionally in the study area, however, it is not known what the exact cause of the “white washing” was, whether it was from undiluted SWP water or some other source. The potential for “white washing” is a concern to some growers.

Elevated nitrogen levels in irrigation water can cause undesired plant growth if management practices are not adjusted, however, this is probably not a concern for Re-circulated Water. The additional nitrogen in the SWP water is minimal, as an increase of 2 ppm NO3 equates to less than 1.5 lb N/ac-ft. As mentioned previously, nitrogen levels in the CVC can be elevated at times when groundwater pump-in programs are operating, and the additional nitrogen from the SWP water would add to the nitrogen that may already be in the CVC.

Table 6.2 presents yield threshold values for EC, boron and chloride when yield reductions may start to appear for crops grown in the study districts.

Table 6.2 – Summary of Crop Sensitivity to EC, Boron and Chloride
Crop Tolerance Before Reduction in Yield

Constituent	EC_w (dS/m)			Boron (mg/L)			Chloride (meq/L)			Total	
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max		
Historical SWP Values (1980-2011)	*0.13*	*0.49*	*1.03*	*0.1*	*0.2*	*0.9*/0.6*	*0.1*	*2.0*	*5.0*	Acres	
Historical SWP Values (2002-2011)	**0.19**	**0.45**	**0.73**	**0.1**	**0.2**	**0.3**	**0.5**	**2.0**	**3.7**	(1990-2002)	%
Alfalfa Hay and Clover	-			-			-			13,127	10.4%
Almonds	1.0			-			<5			33,969	8.0%
Apple, Pear, Cherry, Plum and Prune	1.0 (apples, pears, plums and prunes)			0.5-0.75 (cherry, plum)			<5 (plums)			4,412	1.6%
Citrus	1.0 (lemons), 1.1 (oranges)			0.5-0.75 (orange, grapefruit) <0.5 (lemons)			<5			18,292	3.8%
Corn and Grain Sorghum	1.1			-			-			2,200	7.7%
Cotton	-			-			-			26,382	11.6%
Flowers, Nursery and Christmas Tree	-			-			-			2,616	0.5%
Grain and Grain Hay	-			-			-			5,802	3.5%
Grapes	1.0			0.5-0.75			-			79,082	17.7%
Melons, Squash, and Cucumbers	-			-			-			3,034	0.7%
Misc Subtropical	-			0.5-0.75 (avocado, figs, persimmons)			-			9,467	2.1%
Misc. Deciduous	-			-			-			2,421	0.5%
Misc. field crops	0.7 (beans)			0.5-0.75 (cowpea)			-			1,944	0.8%
Onions and Garlic	0.8 (onions)			0.5-0.75 (onions)			-			316	0.1%
Pasture and Misc. Grasses	-			-			-			840	0.5%
Peach, Nectarine and Apricots	1.1 (peaches and apricots)			0.5-0.75 (peaches, apricots)			<5 (apricots)			4,234	1.0%
Pistachio	-			-			-			4,275	0.9%
Potatoes, Sugar beets, Turnip etc..	1.1 (potatoes)			-			-			21,300	4.6%
Rice	-			-			-			0	0.0%
Safflower and Sunflower	-			-			-			494	0.1%
Small Vegetables	0.7 (carrots), 0.9 (lettuce)			-			-			9,639	2.2%
Strawberries	0.7			-			-			0	0.0%
Tomatoes and Peppers	1.0 (bell peppers)			-			-			3,396	0.7%
Walnuts	N/A			0.5-0.75			-			1,506	0.8%

EC_w threshold from FAO Irrigation & Drainage Paper 29, 1985	Subtotal cropped	248,748	80.3%
B threshold from Mass (1984). Salt tolerance of plants. The Handbook of Plant Science in Agriculture.	Idle	59,907	19.7%
Cl threshold from Mass (1984). Salt tolerance of plants. The Handbook of Plant Science in Agriculture.	Total	308,655	100.0%

Notes:
1) - denotes that threshold tolerance is higher than historical maximum SWP values and no reduction in yield is anticipated
2) * maximum SWP boron level of 0.9 was only 1 value in 32 years (appears suspect - out of range). Practical maximum for boron is 0.6 mg/l
3) Crop acreage for AEWSD, SWID, SSJMUD, KTWD and DEID obtained during Phase I study and generally represent average data from 1990-2002

It should be noted that crops shown above as sensitive and potentially having yield impacts have EC, Boron and Chloride thresholds that are near or slightly below the maximum concentrations of some constituents in SWP water during the 1980-2011 period, while the maximum concentrations in SWP water have generally dropped below the thresholds during the more recent 2002-2011 period.

Table 6.3, based upon university research, gives guidelines for evaluating specific ion concentrations in irrigation water and lists the average and maximum concentrations of the SWP water during the 2002-2011 period and provides a comparison of SJR water.

Table 6.3 – Guidelines for Interpretation of Water Quality for Irrigation[1]

Potential Irrigation Problem	Units	Degree of Restriction on Use				
		None	Slight to Moderate			Severe
Salinity (affects crop water availability)						
ECw	dS/m	< 0.7	SJR_{avg} = 0.07 SWP_{avg} = 0.45	0.7 - 3.0	SWP_{max} = 0.73	> 3.0
TDS	mg/l	< 450	SJR_{avg} = 45 SWP_{avg} = 256 SWP_{max} = 408	450 - 2000		> 2000
Permeability (affects infiltration rate of water into soil. Evaluate using ECw and SAR together)						
SAR = 0 - 3	and **ECw** =	> 0.7	SWP_{avg} = 2.2 / 0.45	0.7 - 0.2	SJR = 0.43 / 0.07	< 0.2
= 3 - 6	and **ECw** =	> 1.2		1.2 - 0.3		< 0.3
= 6 - 12	and **ECw** =	> 1.9		1.9 - 0.5		< 0.5
= 12 - 20	and **ECw** =	> 2.9		2.9 - 1.3		< 1.3
= 20 - 40	and **ECw** =	> 5.0		5.0 - 2.9		< 2.9
Specific Ion Toxicity (affects sensitive crops)						
Sodium (Na)[2]						
surface irrigation[5]	SAR	< 3		3 - 9		> 9
sprinkler irrigation[6]	me/L	< 3	SJR_{avg} = 0.2 SWP_{avg} = 2.1	> 3	SWP_{max} = 3.8	
Chloride (Cl)[2]						
surface irrigation[5]	me/L	< 4		4 - 10		> 10
sprinkler irrigation[6]	me/L	< 3	SJR_{avg} = 0.1 SWP_{avg} = 2.0	> 3	SWP_{max} = 3.7	
Boron (B)[3]	mg/L	< 0.7	SWP_{avg} = 0.2 SWP_{max} = 0.3	0.7 - 3.0		> 3.0
Miscellaneous Effects (affects susceptible crops)						
Nitrogen (NO_3 - N)[4]	mg/L	< 5		5 - 30		> 30
Bicarbonate (HCO_3) (overhead sprinkling only)	me/L	< 1.5	SJR_{avg} = 0.3 SWP_{avg} = 1.4	1.5 - 8.5	SWP_{max} = 2.2	>8.5
pH	Normal Range = 6.5 - 8.4					

[1] Adapted from the FAO 29 Irrigation and Drainage Paper, Ayers & Westcot, 1985.

[2] For surface irrigation, most tree crops and woody plants are sensitive to sodium and chloride; use the values shown. The sensitivity of annual crops varies; use the salinity tolerance tables (Table 5). For chloride tolerance of selected fruit crops, see Reference. With overhead sprinkler irrigation and low humidity (< 30 percent), sodium and chloride may be absorbed through the leaves of sensitive crops. For crop sensitivity to absorption, see Table 7.

[3] For boron tolerances, see Table 8.

[4] NO_3-N means nitrate nitrogen reported in terms of elemental nitrogen (NH_4-N and Organic-N should be included when wastewater is being tested).

[5] Potential root absorption with surface irrigation.

[6] Potential foliar absorption with sprinkler irrigation.

Note: SWP values from 2002-2011

The “normal range” of acidity/alkalinity of irrigation water, as measured by pH, is 6.5 to 8.4. Levels outside of this range can affect a number of plant physiological processes

and soil chemistry to the detriment of crop production. With an average pH of 7.0, SJR water falls within the normal range 95 percent of the time. The remainder of the time the pH is below 6.5. SWP water, with an average pH of 7.6, is more alkaline than SJR water and occasionally exceeds the normal range, varying from 5.9 to 8.8. The difference in pH between SWP and SJR water might have minor affects on the relative availability of nutrients and micro-nutrients to plants. Overall, significant yield reductions due to pH variation are not expected to result from increased deliveries of SWP quality water. The higher pH of SWP water may be of concern related to potential emitter plugging in micro-irrigation systems, which is discussed in a later section.

6.3 – On-Farm Irrigation System Potential Impacts

Use of SWP water in place of SJR water could potentially impact the various components of district distribution systems as well as on-farm irrigation systems, such as pumps and filtration equipment, micro-irrigation system emitters, sprinklers, and pipe, fittings and valves. SWP water quality indicates that the SWP water is slightly more corrosive to metal equipment than SJR water. The SWP water quality may change while it is conveyed through local facilities to its final destination. Such changes would be similar for any water supply delivered, but since SWP water is higher in many constituents than FKC water, the changes may be more likely to elevate these constituents toward levels of potential concern.

Minor increases in the corrosion of metal components of on-farm irrigation systems (in pumps, filter stations, pipelines, fittings, and valves) can be expected as a result of the Re-circulated Water scenarios if the SWP quality water is used for a significant portion of the irrigation season. On the other hand, a minor reduction in erosion rates of concrete facilities can be expected. In addition, the considerably higher buffering potential of SWP water can mitigate some of the acidifying/reduction potential of some pesticides and fertilizers used by the vegetable industry; actually decreasing possible damage to aluminum sprinkler lines that result in "pinhole" leaks.

Both the Friant Division delivery system and the SWP water have periods of high suspended-solids that can increase potential plugging of on-farm irrigation system components and increase maintenance requirements. On average, SWP water is higher in suspended solids than SJR water, although the differences are considered to be minor except when influenced by floodwater “upsets” that can happen on either system. It is anticipated that on-farm filtration systems would remove any suspended solids prior to entering the drip lines.

SWP water does have higher pH levels that sometimes fall within the “slight to moderate” range for potential plugging of micro-irrigation system emitters. This could be mitigated by increased acid injection, although many growers already periodically inject acid into their irrigation systems. Many growers using SJR water also inject soluble gypsum to improve water penetration. While this does not have a major effect on pH, it adds large amounts of free calcium to the water and increases the potential for

lime precipitation around the emitter exit orifice. It is usually these growers that also inject acid for system maintenance and soil fertility reasons. To these growers, the use of SWP water would have virtually no consequence aside from potentially reducing the amount of gypsum they would normally use.

Plugging in micro-irrigation systems can be caused by excessive suspended solids (from inorganic or organic sources), or by the formation of precipitates from insoluble calcium carbonate, iron, manganese, or other chemical reactions. **Table 6.4** presents the primary water quality parameters considered when evaluating the potential for irrigation water to plug micro-irrigation system emitters.

Table 6.4 – Water Quality Influence on Clogging Potential in Localized (Drip) Irrigation Systems[1]

Potential Problem	Units	Degree of Restriction on Use				
		None	Slight to Moderate			Severe
Physical						
Suspended Solids	mg/L	< 50		50 - 100		> 100
Chemical						
pH		< 7.0	SJR_{avg} = 7.0	7.0 - 8.0	SWP_{avg} = 7.6	> 8.0
Dissolved Solids	mg/L	< 500	SJR_{avg} = 45	500 - 2000		> 2000
			SWP_{avg} = 256			
Manganese[2]	mg/L	< 0.1		0.1 - 1.5		> 1.5
Iron[3]	mg/L	< 0.1		0.1 - 1.5		> 1.5
Hydrogen Sulphide	mg/L	< 0.5		0.5 - 2.0		> 2.0

[1] Adapted from Nakayama (1982).
[2] While restrictions in use of localized (drip) irrigation systems may not occur at these manganese concentractions, plant toxicities may occur at lower concentrations (see reference).
[3] Iron concentrations > 5.0 mg/L may cause nutritional imbalances in certain crops (see reference).
These standards are for reduced/soluable forms of Mn and Fe that serve as nutrients/energy sources for slime bacteria and do not include any oxidized forms that come along with suspended solids.

Some plugging of emitters has occasionally been observed by some growers in the study area, and while the plugging seems to manifest itself quickly, the exact cause of the plugging, whether it is from the source water such as SWP water itself or from a chemical reaction caused by farming operations, is unknown.

6.4 – Potential Impacts to Soil Physical Characteristics

The suitability of water for irrigation depends upon both total dissolved solids – often referred to as salinity – and the sodium content in relation to the amounts of calcium and magnesium. When water high in sodium is applied to soil, some of the sodium is taken up by the clay in the soil. The clay gives up calcium and magnesium in exchange

for sodium. The exchange of ions alters the physical characteristics of the soil. Clay that carries a good excess of calcium or magnesium ions tills easily and has good permeability. If the same clay takes up sodium, it becomes sticky and slick when wet and has very low permeability. If the irrigation water contains calcium and magnesium ions in a quantity that equals or exceeds the sodium, a sufficient concentration of calcium or magnesium will be retained on the clay particles of the soil to maintain good tilth and permeability. Such water is excellent for maintaining soil structure and permeability, even though the total mineral content may be higher. For SJR water, the very lack of electrolytes, no matter what the balance, can actually be detrimental to soil structure by causing aggregate dispersion similar to that caused by excess sodium.

SWP water on average has higher sodium, calcium and magnesium levels than SJR water and SWP water has better infiltration characteristics than does SJR water, which has lesser amounts of sodium, calcium and magnesium. Thus an improvement in infiltration can be expected and potentially a decrease in the need for the use of gypsum, manure, green-waste, and other soil/water amendments could be expected as a result of greater use of Re-circulated Water in lieu of CVP SJR water.

Soil salinity and specific ion increases associated with SWP water can be mitigated with adequate drainage and leaching salts out of the root zone, however leaching can lead to salt accumulation of the groundwater aquifer. Most of the study area is known to have good drainage, but some small isolated areas with drainage impairments may exist, and in these areas, drainage may be inadequate to allow for the extra leaching requirement.

Differences in mechanical compaction would be expected to be minor, and if anything, improved by use of SWP water.

6.5 – Potential Impacts to Soil Amendment/Fertilizer Practices

A wide variety of practices are known to be employed by growers to manage and mitigate the reduction in infiltration rates that often accompany the use of CVP SJR water, due to its extremely low salinity. The exchange of SWP water for CVP SJR water may allow growers to modify those practices when Re-circulated Water is being received. Of particular interest are changes in soil amendment practices, and possibly fertilizer practices. Addition of gypsum to soil or water increases salinity, reduces the Sodium Adsorption Ration (SAR) and increases the relative ability of water to penetrate the soil. The amount of gypsum used by Friant service area growers may be able to be reduced since there are less potential infiltration problems associated with SWP water. However, additional salt imported with SWP water will only be partly offset by a reduced need to apply gypsum to Friant water since not everyone experiences reduced penetration problems with Friant water, and not everyone will change gypsum applications if they don't know the source water they are receiving or the properties of the source water.

Gypsum is applied mostly by chemical injection, but some is applied by land application. Chemical injection of soluble gypsum could be modified when water supplies change, if growers are informed of when changes in water quality will occur and how long the use of Re-circulated Water will last. Land application of gypsum is usually performed once a year, so it is unlikely that land applications will be reduced unless a district consistently receives SWP quality water every year for longer periods of time and its outreach efforts are effective in educating its customers of the expected water supplies. It should be noted that if the soil is naturally impermeable because of fine texture or restrictive layers in the subsurface, infiltration improvement by gypsum may not work at all as these other factors are more problematic than poor aggregation at the soil surface.

Reductions in gypsum, manure, and green waste applications used to combat infiltration problems may be possible if SWP quality water were exchanged for SJR quality water. This may partially offset the expected increased salt load to soil and groundwater associated with the exchange from bringing additional SWP quality water into the district. However, several thousand acres of organic production in these water districts depend on manures and composts for supplying required crop nutrition. Reduction of these amendments to these fields is unlikely even with a change in water source.

The use of SWP quality water should reduce the need for use of gypsum, manure, and green waste for combating infiltration problems for most of the studied district areas. To estimate the potential for reducing soil amendments, a calculation was performed during the Phase I Study that indicated that about 0.25 ton/acre-foot (500 lbs) of salt would be required to give the Friant water an infiltration characteristic equivalent to SWP water. Thus, theoretically, exchanging SWP water for Friant water would have the potential for reducing gypsum use by up to 500 lbs (on a net salt content basis) per acre-foot. Actual reductions would likely be less, as management practices would not be expected to perfectly match the potential for reductions. It is fair to assume that additional salt loads within the Friant service area due to gypsum applications could easily be reduced by 500 to 1,000 lbs/acre/year if growers did not use gypsum when irrigating with SWP quality water.

The tradeoff between decreased gypsum application and increased salt load in SWP water is not a "zero sum game", even if the mass of the salts were equal. Much of the salt in the SWP water is sodium and chloride, which are much more mobile and, pound for pound, potentially more damaging than calcium and sulfate. With respect to manures and composts, it is impossible to predict likely changes in organic based soil amendments as these materials are also used for benefitting soil fertility. These materials also carry a significant amount of sodium and chloride as soluble salts.

Based on interviewers with local growers and professional agronomists it was concluded that the growers would probably not modify their gypsum application as a result of changing the source water. **Appendix B – Peer Review Comments** includes more detail on these interviews and a list of arguments supporting this conclusion.

6.6 – Potential Impacts to Leaching Requirements

Deep percolation is the amount of water that passes below the root zone. Deep percolation can be thought of as being made up of two components. The first is water flowing past the root zone due to the irrigation techniques used causing non-uniform application of water, plus any over irrigation that occurs. No irrigation system is 100 percent uniform in applying water across a field. Unless the field is deficit irrigated, all irrigation systems over-irrigate some parts of the field so that the required amount of water will be applied to the majority of the field. The second component of deep percolation is that amount of water provided to leach salts from the root zone. Leaching practices have ramifications for water supply (i.e. affect how much water is purchased and applied), soil chemistry (how salts and boron accumulate in the root zone), and on leachate water quality (salts, boron, nitrates, pesticides, and other elements that pass into the vadose zone and groundwater).

Adequate leaching (water passing through and below the root zone) is necessary to keep excessive amounts of salts from building up in the root zone and affecting crop production. The leaching requirement (LR) is the fraction of applied water required to maintain a desired salinity level in the soil at the spot in the field, which receives just enough water to match evapotranspiration requirements. As the salinity of the irrigation water increases, the amount of water needed for leaching also increases.

SWP water has higher salinity and specific ions such as Sodium, Chloride and Boron and thus higher leaching requirements than SJR water. If deep percolation from irrigation inefficiencies do not provide sufficient leaching, then, to avoid salt build-up, a slight increase in applied water would need to be associated with water quality exchanges to provide adequate leaching. The additional salt leaching requirement for SWP water (in comparison to CVP water) is estimated to be a 5 to 6 percent increase in the leaching fraction when sensitive crops are irrigated.

Although the boron concentration in the SWP water is fairly low on average, there is a potential for some boron concentration in some areas. Boron is much more difficult to leach than chloride and sodium. Boron moves slowly with the soil-water and requires about three times as much leaching water as would be needed to reduce an equivalent amount of chloride or salinity. Boron concentration in the soil profile may be a concern in some portions of the study area, especially where boron is present in the groundwater, and additional leaching may be required in these areas to maintain the soil boron concentration at acceptable levels.

If a farmer's distribution uniformity is low, then certain areas of a field may not be receiving enough water for leaching or even crop demands. Some salt buildup in the soil may occur in these under irrigated areas, and these areas could require more water for leaching if SWP supplies are used to prevent additional salt build-up. This could be remedied by improving irrigation methods and thus improving the distribution uniformity. From a practical standpoint, however, it may be that current crop rotations and

establishment practices, irrigation non-uniformity and certain cultural practices such as winter irrigation for frost control and recharge of permanent crop root zones are adequate to cover the extra 5 percent to 6 percent leaching requirement needed for sensitive crops that use only SWP quality water.

6.7 - Conclusions

Many factors exist that create variability in soils or crop responses besides water quality, which makes predicting definitive impacts difficult. Individual fields will respond differently, independent of soil type, depending upon the past and future cultural practices of soil manipulation such as ripping, deep plowing, non-tillage and cover cropping. Individual sites may be more impacted if practices encouraging either excessive leaching or lack of sufficient irrigation are employed. The overall agronomic risk caused by the importation and exchange of SWP quality water for CVP SJR water should be minimal in a general sense, although there are some minor potential impacts.

Management practices, including monitoring, blending, avoidance, and irrigation system changes might be needed under certain conditions to mitigate these concerns where a change in source water quality has occurred such as with the studied Re-circulated Water scenarios.

The following conclusions can be drawn from the agronomic impact analysis:

Crop Yields. Salinity, sodium, chloride, and boron levels in SWP quality water can sometimes reach levels that could cause yield loss impacts to the most sensitive crops under certain conditions, if that quality of water was used for the whole crop season. The crop tolerance thresholds for EC, Boron and Chloride assume long-term irrigation with that quality of water. It is unknown when the Re-circulated Water will be received by the districts, or for how long, although in some cases the Re-circulated Water could be available for nearly the entire year. Since the SWP water quality data indicates that most of the maximum constituent values in SWP water occur during the winter when irrigation is not heavily occurring and the SWP water quality is generally better than average during the summer months when most irrigation will occur, it is anticipated that there are no crops grown in the area that would experience toxicity or significant yield impacts from use of the Re-circulated Water.

Irrigation System Impacts. Minor increases in the corrosion of metal components of district and on-farm irrigation systems (in pumps, steel tanks, filter stations, pipelines, fittings, and valves) could occur as a result of the use of Re-circulated Water if a significant amount of SWP quality water is delivered. On the other hand, a minor reduction in erosion rates of concrete facilities can be expected. In addition, the considerably higher buffering potential of SWP water can mitigate some of the acidifying/reduction potential of some pesticides and fertilizers used by the vegetable industry; actually decreasing possible damage to aluminum sprinkler lines that result in "pinhole" leaks.

SWP quality water has higher potential to plug emitters, due to higher pH levels. This could be mitigated by increased acid injection. However, many growers using Friant water also inject soluble gypsum to improve water penetration. While this does not have a major effect on pH, it adds large amounts of free calcium to the water and increases the potential for lime precipitation around the emitter exit orifice. It is usually these growers that also inject acid for system maintenance and soil fertility reasons. To these growers, the use of SWP quality water would have virtually no consequence aside from potentially reducing the amount of gypsum they would normally use, however it is unlikely that growers would change their historical practices and as such the gypsum use is not anticipated to be reduced.

Soil Physical Characteristics. SWP water has better infiltration characteristics than does CVP SJR water and helps maintain soil structure. Thus an improvement in infiltration or a decrease in the need for the use of gypsum, manure, green-waste, and other soil/water amendments can be expected. Soil salinity and boron increases associated with SWP quality water use can be mitigated with adequate drainage and leaching. In some areas, drainage may be inadequate to allow for the extra leaching requirement. Micro-irrigation systems are used in all of the studied districts to irrigate a number of crops, especially trees and vines. Micro-irrigation maintains the salt balance in the root zone of individual plants, but does not maintain the salt balance in the entire field. This allows for much less water use but causes salts to accumulate in the soil, potentially increasing the complexity of managing and irrigating the crop. According to the dominant soil types in each studied district, which are all moderately to well drained, none of the districts are expected to experience a problem with salt accumulation in the root zone if an exchange of source waters occurs. Differences in mechanical compaction would be expected to be minor, and, if anything, improved by use of SWP quality water.

Soil Amendments/Fertilizers. The use of SWP quality water should reduce the need for use of gypsum, manure, and green waste for combating infiltration problems for most of the studied district area. The potential for reducing gypsum is as high as 500 lbs (on a net salt basis) per acre-foot of exchanged water. Actual reductions would likely be less, as management practices would not be expected to perfectly match the potential for reductions. It is anticipated that growers would be more likely to reduce soil amendment applications when receiving SWP quality water if the SWP quality water is received during known periods of time, than if the water sources are constantly changed. Several thousand acres of organic production in these water districts depend on manures and composts for supplying required crop nutrition. Reduction of these amendments to these fields is unlikely even with a change in water source.

Leaching Requirements. SWP quality water has higher salinity and thus higher leaching requirements than CVP SJR water. If deep percolation from irrigation inefficiencies does not provide sufficient leaching, then, to avoid salt or boron build-up in

some areas, a slight increase in applied water would need to be associated with water quality exchanges to provide adequate leaching.

7 – OPERATION AND MAINTENANCE IMPACTS

This section describes potential impacts to corrosion, material degradation, and distribution systems from the use of Re-circulated Water in the Friant Division service area. These topics were initially evaluated by Provost & Pritchard (2006c), with assistance from V&A Consulting Engineers, a consulting firm that specializes in corrosion engineering.

7.1 - Corrosion Impacts

Re-circulated Water differs from San Joaquin River water in several constituents that can impact corrosion. Consequently, a comparison of the corrosivity of both water sources was performed with the following goals:

1. Evaluate and compare the water chemistry and corrosion potential of the two water sources.
2. Estimate possible changes in corrosion/degradation to metal, concrete, and plastic materials that are used in facilities such as pipelines, valves, canal linings, pumps, trashracks, etc.
3. Recommend potential preventative measures and estimate increases in maintenance costs.

Comparison of Water Quality and Corrosiveness

The corrosiveness of the two water sources was compared based on several chemical constituents and calculated indices that can have a notable impact on corrosion potential. These include the Langelier Saturation Index and Ryzner Index (both indicate the tendency to form protective calcium carbonate scales), resistivity, chloride concentration, sulfate concentration, and acidity.

A comparison of these indicators generally showed that San Joaquin River (SJR) water will not have a tendency to form a protective calcium carbonate layer, and will have a slight tendency to degrade concrete structures by leaching out minerals. Heavy concrete materials would be expected to have a long life exposed to both water sources, but it is likely that thin mortar linings, like those commonly used on ductile iron and steel water pipe, will not last as long in SJR water. SJR water will also have a greater tendency to degrade asbestos cement pipe. However, based on the resistivity, the SJR water is not corrosive enough to initiate significant metallic corrosion.

SWP water similarly will not form a calcium carbonate protective coating, but will have a lower tendency to leach out the minerals from concrete. The resistivity indicates that SWP water will have a more corrosive effect on metallic surfaces than SJR water, although the difference is not large.

Materials such as brass, bronze, PVC, polyethylene, and stainless steel usually have a high corrosion tolerance, and therefore they likely will not be affected by a change of source waters.

Corrosion Impacts on Material Types

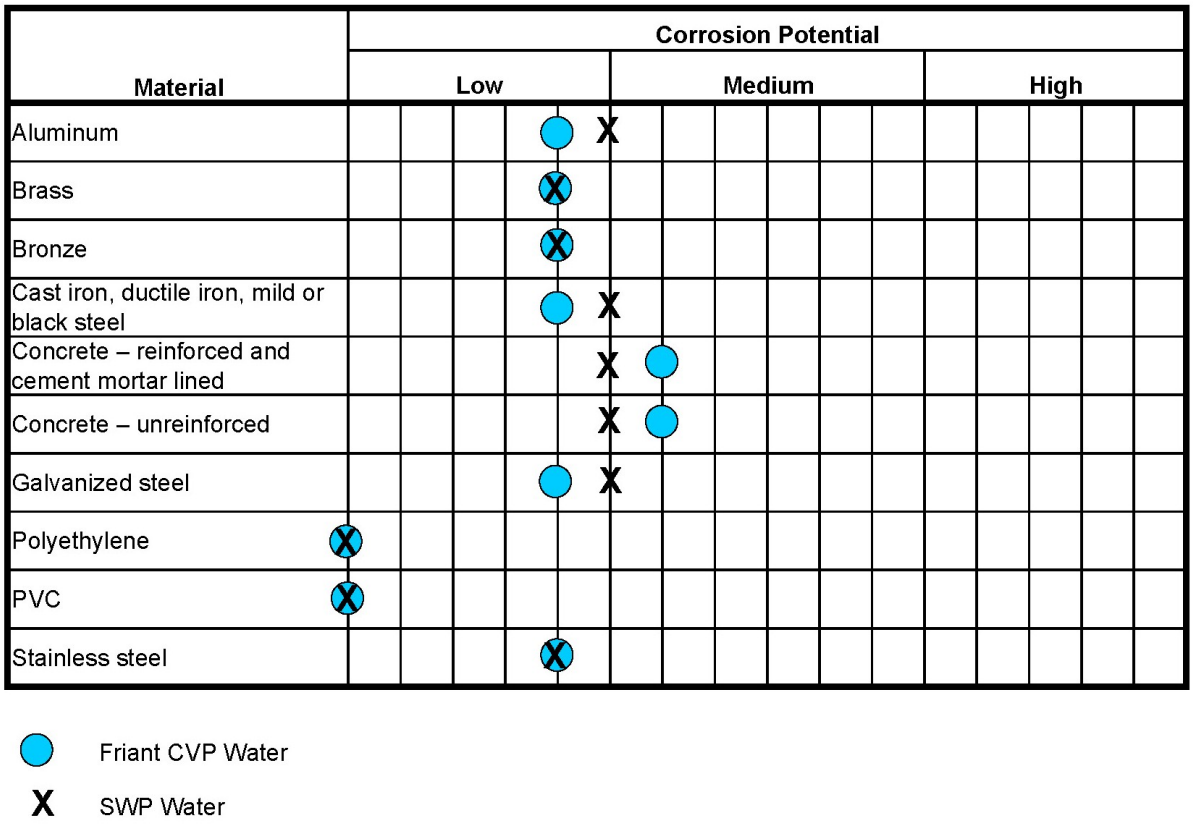
A corrosion rating scale was developed with three general categories: low, medium and high. General descriptions for these categories are shown in **Table 7.1**.

Table 7.1 – Definition of Overall Corrosion Rating

Corrosion Potential	Degradation Potential
High	Mitigation measures should be taken as soon as possible
Medium	Mitigation measures should be taken within 2-3 years
Low	Mitigation measures should be taken within 5-10 years

Figure 7.1 provides a comparison of the corrosion impacts from the two water sources using the overall corrosion rating described in **Table 7.1**.

Figure 7.1 - Relative Corrosion Impacts from Different Water Sources



The corrosion potential for both water sources is considered low for all materials with the exception of concrete in FKC water, which is on the lower threshold of a medium corrosion potential.

Interviews with Agencies

Interviews with three agencies (Friant Water Authority, Department of Water Resources, and San Luis and Delta-Mendota Water Authority) that use San Joaquin River water or SWP (or equivalent) water confirmed the results of the corrosion analysis. These agencies do not individually use/experience both water qualities. The interviews also concluded that galvanizing is not suitable protection for SWP quality water, and that rubber degradation is negligible in both water sources.

Operation and Maintenance

Based on their experience, V&A Consulting Engineers estimated that use of SWP quality water would increase existing operation and maintenance (O&M) costs between 10 percent and 15 percent per year. The increase in O&M costs will likely vary by district according to the types of facilities they possess, the condition of the facilities, their existing maintenance program, and the volume of water exchanged. Most of the additional costs would be for periodic application of protective coatings on metallic components. Cement based protective coatings, which have proven to be the most

common and effective protection for cast iron, ductile iron and steel pipe, are likely to have a longer life expectancy in SWP quality waters. This increase in costs is based on a 100 percent replacement of CVP SJR water with SWP quality water. Table 4.7 shows that average annual CVP use in the studied districts is 410,000 AF, and Re-circulated Water deliveries would average 58,400 AF/year, or a replacement of about 12 percent. The increase in O&M costs should therefore be less than the estimated 10 to 15 percent.

Results

The following conclusions can be taken from the corrosion analysis:

1. Re-circulated Water could result in a minor increase in corrosion to metals.
2. Materials such as brass, bronze, PVC, polyethylene, and stainless steel usually have a high corrosion tolerance, and therefore they likely will not be affected by the change of source waters.
3. The forecasted increase in corrosion is manageable. The amount of corrosion can be maintained at existing levels, and current life expectancies maintained, with the addition of various corrosion prevention measures, such as special coatings or selection of proper materials for new facilities.
4. Re-circulated Water has lower potential to cause degradation by leaching minerals from concrete; this could result in lower concrete maintenance costs. However, with the additional potential for metal corrosion it is anticipated that there will still be an overall increase in maintenance costs.
5. Based on their experience, V&A Consulting Engineers estimated that use of Re-circulated Water would increase existing operation and maintenance (O&M) costs between 10 percent and 15 percent per year. However, this estimate was based on a 100 percent exchange of CVP SJR water for SWP quality water, so the cost increase would likely be lower.

7.2 – District Distribution System Impacts

This section describes potential impacts to district distribution systems from importing Re-circulated Water including sedimentation, changes to infiltration rates, recharge basin sealing, abrasion and wear on equipment, and biological growth (irrigation emitter plugging is discussed in Section 6 – Agronomic Impacts). These topics are addressed through qualitative and anecdotal discussions, and the results of interviews with several agencies that use San Joaquin River water and SWP water.

Sedimentation

Sedimentation is largely determined by total suspended solids (TSS) in the water. The TSS value in both water sources is generally low on average. Sediment accumulations in reservoirs and recharge basins should be minimal using 100 percent of average quality SWP water, even over extended periods of time, although there could be some

surface sealing affects. Localized concentrations of sediment could occur, however, in certain areas (intakes, abrupt changes in geometry, etc.). Sediment accumulations in canals and pipelines are reported to be small by agencies using both water supplies.

Sedimentation in pipelines can usually be mitigated by flushing the pipelines at higher velocities. If the pipeline is normally operated at a relatively high velocity then flushing may never be required. Sedimentation in canals and reservoirs is difficult to estimate and depends not only on the quality of the source water but also the water velocities, facility dimensions, and settling times. While some sediment may settle in agricultural fields, it would likely be spread over such a large area that the impact would be negligible. Sediment accumulation would probably only be noticed in water bodies such as canals, forebays, standtanks, reservoirs, and recharge basins.

TSS in SWP water at Check 21 averaged 32 mg/L during the summer period (March - September) from 1994 to 2003. TSS at the Friant-Kern Canal terminus is 5 mg/l, based on three years of data collected by USBR (2009). As a result, sedimentation can be expected to be six (6) times higher when using Re-circulated Water.

Table 7.2 shows the total estimated volume of sediment that would be imported into recharge basins if DEID and AEWSD used undiluted Re-circulated Water for all of their groundwater recharge. The calculations are based on average TSS in SWP water (32 mg/L). The results show that accumulation in reservoirs and recharge basins would be negligible, even over extended periods of time. However, localized concentrations of sediment could occur. Parties at the end of a distribution system may experience the greatest impacts.

Table 7.2 – Estimated Sedimentation in Recharge Basins

District	Recharge Basin Area (acres)	Average Annual Recharge (AF)[1,2]	Suspended Solids Imported		10-year Accumulation (in)
			Tons/year	AF/year	
AEWSD	1,350	52,000	2,263	1.99	0.21
DEID	165	6,100	265	0.23	0.17

1. Average recharge for AEWSD is from 1990 to 2002 time period.
2. Average recharge for DEID is based on 2009 to 2011 after new facilities were completed; this differs from the value used in the water balance.

The Friant Water Authority, San Luis Delta and Mendota Water Authority, and Department of Water Resources were interviewed a part of the Phase I Study to collect information on their experience with sedimentation while using CVP SJR water or SWP water. The following conditions were noted:

- Sediment accumulation in pipelines and canals is generally not a problem for either water source as the water velocity is sufficient to transport sediments. Some

sediment accumulation, however, does occur around turnouts and subsidence areas, which is common in most canals.

- Reservoir sedimentation is a minor problem with San Joaquin River water but can be problematic at times when using SWP water.

Infiltration Rates

Infiltration rates in reservoirs have the potential to change while using SWP water, but the magnitude of the change is difficult to quantify because it depends to varying degrees on several parameters, including biological growth, salinity, sediment content, and temperature. Methods are readily available to modify infiltration rates, if needed, although they can be costly.

Infiltration in conveyance systems and recharge basins can be influenced by the source water. Water properties such as sediment content, salinity, biological growth, and temperature are all known to impact infiltration rates. Increasing infiltration rates at recharge basins is desirable. However, increasing recharge rates in canals or reservoirs can be beneficial or detrimental, or neither, depending on whether the district depends on the canals and reservoirs for groundwater recharge.

Estimating the change in infiltration from a water source exchange is difficult because some properties of SWP quality water, such as the level of salinity, can increase infiltration, while other factors, such the higher temperature and sediment content, can decrease infiltration. Following are discussions on how these factors impact infiltration.

Sediment. Spreading of waters containing large quantities of silt can clog soil pore space and cause a rapid decrease in infiltration rate. Sediment, measured as total suspended solids (TSS), was found to average 32 mg/l in SWP water, compared to 5 mg/l in CVP SJR water or six (6) times higher.

Biological Growth. If water is applied to recharge basins for long continuous periods, experiments have shown that a decrease in rate of intake results largely from micro-organism activity within the soil or biological growth in the water. SWP water would likely have a lower level of biological growth than FKC water and hence have less effect on infiltration rates.

Salinity. In general, increasing water salinity increases infiltration rates in most soils, although sodium based salinity can decrease infiltration. Infiltration problems associated with low salinity CVP SJR water are well known and commonly experienced by Friant Division farmers. Users of SWP water also experience some infiltration problems, but they are less severe than those caused by CVP SJR water. Hence, a switch to Re-circulated Water could increase infiltration rates in canals, reservoirs, and recharge basins.

Temperature. Water temperature is known to have some affect on infiltration rates. The USDA published a study in 1937 entitled *Spreading Water for Storage Underground*. The study documented experiments that showed a sharp reduction in infiltration during a 24-hour period due to higher water temperatures. However, it has been reported that infiltration rates were observed to increase with temperature at the Leaky Acres Project in Fresno, and the Madera Ranch Pilot Project in Madera Irrigation District. Therefore, the impact of water temperature on infiltration rates is inconclusive. Only limited data on FKC and SWP water temperatures are available. However, a comparison of the limited data shows that FKC water is typically at least a few degrees cooler than SWP water. The different temperatures of the two water supplies would likely cause some difference in infiltration rates, but the difference is difficult (or impossible) to estimate without specific testing.

Numerous methods are available to manage and reduce recharge basin sealing, although they all require investments of time and money. These methods include settling basins, dredging, earthwork (sediment removal), and exclusion of water with high sediment content (not recharging with water that has high TSS loads as a result of storm events).

Abrasion

Abrasion and wear on equipment is difficult to quantify using only water quality data. However, interviews with several agencies seem to conclude that neither Friant nor SWP water will cause any significant wear on equipment.

Algae Growth

Biological growth, primarily algae, can impact numerous aspects of a water system including reducing flow rates in canals, reducing infiltration rates in recharge basins, plugging irrigation emitters, and causing odor problems for treated water. Biological growth is influenced by the opacity of the water and nutrients available in the water supply.

During the Phase I Study, interviews were conducted with several agencies that use San Joaquin River water and SWP water to ascertain the level of biological growth typical in each water supply. The following was concluded from the interviews:

- FKC has low nutrients levels to support algae, but the high clarity permits abundant sunlight to penetrate the water allowing algae to grow. However, copper sulfate is an effective algaecide in the FKC.
- SWP quality water has higher nutrient contents to support algae, but the lower clarity (due to the higher sediment content) inhibits sunlight penetration and algae growth. Nonetheless, some algae does grow. The Metropolitan Water District of Southern California and Los Angeles Department of Water and Power have had extensive problems with algae in SWP water, but copper sulfate has been effective in treating the algae.
- Although no quantitative data is available, it appears that CVP SJR water experiences slightly higher algal growth than SWP quality water. This experience is substantiated with observations by the Arvin-Edison Water Storage District.

Weeds

Due to water quality concerns for drinking water, the Cross Valley Canal (CVC) has no chemical weed control program, although some mechanical removal is performed. AEWSD reports that they divert a lot of weeds into their system when they use CVC water. Since re-circulated water will be delivered through the CVC, all impacted districts will have to deal with additional weeds in their water supply.

Results

The following conclusions can be drawn on the potential impacts to distribution systems from importing Re-circulated Water:

1. Additional sediment accumulations in pipelines and canals would be negligible.
2. Additional sediment accumulation in reservoirs, and especially at turnouts and subsidence areas, would occur with the use of more SWP water.
3. The infiltration rate has the potential to change, but the magnitude of the change is difficult to quantify because it depends to varying degrees on several parameters (biological growth, salinity, sediment content, and temperature).
4. Abrasion and wear on equipment is not a major concern for either water source.

5. CVP SJR water probably experiences higher algal growth than SWP water, but the problem is manageable with copper sulfate.

8 – WATER MANAGEMENT IMPACTS

This section discusses potential impacts to existing water management programs within each studied district. Potential impacts to water sales, transfers, exchanges, and banking agreements were evaluated for each of the districts. These programs could potentially be impacted from increased competition for water supplies, access to water storage facilities, and access to water conveyance facilities if Re-circulated Water is delivered to the area.

Following is a general qualitative discussion on potential water management impacts. Refer to the Phase I Study on Water Management Impacts (P&P, 2006d) for more detail on potential water management impacts. Some of the impacts described herein are based on interviews with district staff in 2006 for the Phase I Study, and updated to reflect current conditions. The districts were not re-interviewed for this Re-circulated Water study.

8.1 - Volume and Timing of Re-circulated Water Supplies

According to USBR (2010) Re-circulated Water deliveries will vary from 0 to 250,000 AF/year, with an average of about 58,400 AF/year. In comparison, long-term average CVP deliveries to the studied districts have historically been about 410,000 AF/year.

The impacts to water management programs will largely depend on the period (months) when Re-circulated Water is delivered. However, there is some uncertainty when the water will be delivered, and the delivery period will be different each year due to varying hydrologic conditions. The Programmatic Environmental Impact Report (PEIR) for the San Joaquin River Restoration Program made no attempt to allocate the potential return to individual years or months because the mechanism and facilities required to implement the returns, either existing or new, were considered unknown at the time.

Most of the restoration releases will occur in the spring, however that water will enter the Delta or San Luis Reservoir and become mixed with the overall water supply, and released to the impacted Districts when convenient. Nevertheless, three possible scenarios have been identified that will determine when the Re-circulated Water is to be available:

1. SJR/Millerton Lake water could be released to the San Joaquin River, and then pumped out at the State or Federal Delta pumps, and delivered to the studied districts (Re-circulated Water). However, Delta pumping restrictions could restrict when the water is pumped, and there may be a delay between delivery and pumping out of the Delta.
2. Re-circulated Water could be stored in San Luis Reservoir and delivered to the studied districts when they have demand and conveyance facilities are available. However, storage space in San Luis Reservoir is limited and the reservoir sometimes reaches full capacity.

3. Re-circulated Water could be recaptured and pumped from the lower San Joaquin River into the California Aqueduct (or the Delta-Mendota Canal) and never reach the Delta. If this occurred then the water would be delivered to the districts within a few weeks after being released from Friant Dam (unless it is stored in San Luis Reservoir). Restoration flows could occur in all 12 months, but the majority of the flows are expected to be from March to June (Spring Run) as well as November (Fall Run).

8.2 - General Impacts

All of the studied districts engage in some water management programs with the goals of improving their water supply reliability, improving water use efficiency and realizing cost-savings. The terms and conditions of these programs may present institutional or contractual constraints to the Re-circulated Water deliveries, or they may themselves be impacted by the deliveries. The first key to understanding potential impacts is knowledge of existing water management programs (sales, transfers, exchanges, and banking agreements). Specific programs for each district are discussed later.

Impacts to water management programs could fall under three general categories:

1. Competition for Water Conveyance Facilities;
2. Competition for Water Storage Facilities; and
3. Water Quality Impacts.

A discussion on each of these general categories follows.

Competition for Water Conveyance Facilities

Competition for conveyance facilities may increase when Re-circulated Water is delivered. The Re-circulated Water would potentially need to use the CVC (rated at 1,400 cfs in forward flow, west to east), FKC (rated 2,500 cfs in the last reach) and various intra-District facilities. CVC is inherently a “smaller” canal than FKC and accordingly Re-circulated Water will have less opportunity to be conveyed versus the base case of SJR CVP in the FKC. While some existing programs would have priority over the Re-circulated Water deliveries, others may not. In addition, some facilities are not always used at their full capacity. This provides flexibility to other water users who may regularly take advantage of the unused capacity. Some of this flexibility may be used to deliver Re-circulated Water. Currently, the CVC is at times heavily used and actively managed. The CVC has established user priorities for the custom transporting (wheeling) of water.

The FKC is envisioned to flow in reverse direction to deliver Re-circulated Water, possibly inhibiting or delaying exchanges that otherwise would occur during this time period. Some existing water exchanges and transfers will still be possible while Re-circulated Water is delivered, but their timing may be impacted.

Competition for Water Storage Facilities

The studied districts store water in various reservoirs on the eastside of the San Joaquin Valley. The districts have limited storage allocation in the reservoirs and generally try not to exceed these allocations or they risk losing a portion of their water supplies as a result of flood control spills, seepage and/or evaporation. A dilemma could occur if Re-circulated Water is allocated for specific delivery patterns while, at the same time, the districts need to release water from reservoirs or risk losing the water. In addition, the districts may want to temporarily store their Re-circulated Water in San Luis Reservoir, which is already in high demand in the spring and early summer of most years.

Water Quality Impacts

The studied districts expect to receive Re-circulated Water, and deal with any associated impacts. However, if the districts practice local exchanges while the Re-circulated Water is being delivered, then the local exchange partners might receive some Re-circulated Water. These local exchange partners may or may not accept the Re-circulated Water depending on their perceptions of the water supply (political decisions on picking up water in Delta) and/or potential impacts to their crops, distribution system, and groundwater quality. This could be problematic if an exchange is based on water quality, in which case the exchange partner would likely not accept the Re-circulated Water.

8.3 - Arvin-Edison Water Storage District

The Arvin-Edison Water Storage District's (AEWSD) strategic physical location, its interconnections to major Federal, State, and local water conveyance facilities, and its versatile delivery and water banking facilities give AEWSD a unique ability to facilitate various transfers and exchanges. As a result, AEWSD and its exchange partners have been able to realize water management benefits. Some of the major water exchanges could be potentially impacted by delivery of Re-circulated Water.

Cross Valley Canal Exchanges

During 1974, the District entered into agreements for participation in the construction and operation of the CVC with the Kern County Water Agency and other participants. AEWSD also entered into water exchange agreements with eight other public agencies located on the east side of the San Joaquin Valley. The CVC Exchange agreements provide an exchange of the AEWSD's Friant CVP SJR water for federal or State supplies from Northern California via the Sacramento-San Joaquin River Delta and typically delivered to AEWSD through the CVC and/or its California Aqueduct turnout. While the overall volume of this exchange (including partners) has decreased somewhat over the years, the Re-circulated Water deliveries will put additional demand on the CVC.

AEWSD/MWDSC Water Management Program

In December 1997, after more than 10 years of planning and negotiations, AEWSD entered into a 25-year water management program with MWDSC. Under the banking and exchange agreement, AEWSD agreed to bank a minimum of 250,000 AF of MWDSC water and return the water in certain drought years. Return water to MWDSC is to be delivered during AEWSD's off-peak periods so as not to interfere with normal, historic operations to its customers/water users. The Re-circulated Water deliveries may impact when AEWSD can pump and deliver groundwater to MWDSC given the reduction in the Re-circulated Water's scheduling flexibility compared to AEWSD's CVP SJR supplies. The improved water quality benefits to MWDSC of the exchange could also be reduced given a lesser availability to AEWSD of CVP SJR supplies to provide in the Exchange, when applicable (consolidated place of use issues).

AEWSD's return water would experience different blending of supplies (i.e. constituents of concern) given the more frequent mixing of CVC water with groundwater vs. CVP SJR water.

Exchanges with Kern-Delta Water District

During the 1990's, temporary interties between Kern-Delta Water District's (KDWD) canals and the AEWSD Intake Canal were constructed and utilized by both districts to facilitate mutually beneficial exchanges. These temporary interties were recently upgraded to more permanent facilities with increased capacities as well as better flow measurement. KDWD may receive Re-circulated Water at times, as opposed to CVP SJR or Kern River water when wheeling in AEWSD's Intake Canal.

Outside Banking Partners

AEWSD could now include Re-circulated Water as a part of their portfolio to expand on its existing management programs (i.e. Rosedale Rio Bravo Water Storage District, MWDSC) and accordingly its partners may see a variety of supplies and/or a larger amount of SWP/CVC water instead of CVP SJR water.

8.4 - Shafter-Wasco Irrigation District

Shafter-Wasco Irrigation District has several interties with neighboring districts, and participates in several out-of-district banking projects. It is not anticipated that any of these programs would be impacted by the delivery of Re-circulated Water.

8.5 - Southern San Joaquin Municipal Utility District

The Southern San Joaquin Municipal Utility District (SSJMUD) performs several types of exchanges and transfers. The loss of these programs would not significantly affect SSJMUD or their exchange partners, because none of the exchange partners depend on SSJMUD to consistently shore up their water supplies or exchange water for purposes of improved water quality.

Late Season Water Exchanges

SSJMUD sometimes exchanges water with other agencies and uses the water late in the irrigation season because the other districts cannot use their full allocation in that year. SSJMUD uses the exchanger's water in the fall and then returns an equal amount of water at the beginning of the next irrigation season. These exchanges generally take place in the late summer/early fall and late winter/early spring. These exchanges may not be possible while the FKC is flowing in reverse.

Wet Season Water Transfers

SSJMUD sometimes transfers water out when surpluses develop as a result of extended cool and/or wet weather conditions. In some cases, the USBR has made late season declarations after SSJMUD demands have been mostly met resulting in a temporary surplus of water for SSJMUD. Other districts that have the ability to store water via groundwater recharge and banking are usually in the market to take this water from SSJMUD or, in some cases, SSJMUD can carry it over into the next water year. In 2005, SSJMUD transferred out 21,392 AF and a similar quantity was transferred out in 2004. These were one time transfers and SSJMUD has no obligation to continue with any of the transfers and none were exchanges where SSJMUD is expecting to get water back at some future date. These transfers are typically made in the fall, and may be impacted if Re-circulated Water is delivered at the same time, but only if the transfers are made with contractors located in downstream reaches of the FKC, such as SWID or AEWSD.

Transfers with Kern-Tulare Water District

SSJMUD routinely transfers (in wet years) or wheels (in dry years) water to the neighboring Kern-Tulare Water District (KTWD). KTWD is located along SSJMUD's east boundary, so water is transferred preferably to them to reduce their groundwater pumping, which will also improve SSJMUD's groundwater conditions. These transfers are performed according to a long-term agreement and should not be impacted by the Re-circulated Water deliveries. However, KTWD may be receiving SWP quality water in place of SSJMUD's CVP SJR water. Such water quality impacts of a changed water source to KTWD are already being analyzed elsewhere as part of this study.

Transfers to Alpaugh Irrigation District

SSJMUD transfers water to Alpaugh Irrigation District (AID or Alpaugh) in order to: (i) reduce the costs to the Alpaugh farmers and (ii) improve Alpaugh's and SSJMUD's groundwater conditions by turning off Alpaugh's deep wells in favor of using surface water. The availability of water to Alpaugh should not change as a result of the proposed exchange. However, it is envisioned that Alpaugh could directly receive the Re-circulated Water in place of the current transfers of CVP SJR water from SSJMUD, and thus receive water with different quality.

8.6 - Kern-Tulare Water District

Kern-Tulare Water District (KTWD) believes there will be financial impacts to them when Re-circulated Water is delivered due to increased competition for conveyance capacity. KTWD currently obtains much of their water supply by exchange agreements with AEWSD. Under the agreement they take AEWSD's CVP SJR water from the FKC in exchange for delivering their own water supplies from the California Aqueduct, through the CVC, and into AEWSD's Intake Canal or their Kern River supplies. This agreement prevents the need to take direct delivery of their Delta originated CVP supplies from the CVC and the required pumping of the KTWD's water supplies upstream in the FKC (reverse flow), thus simplifying operations, eliminating Warren Act charges and reducing pumping costs.

Potential negative impacts from the water quality exchange could be increased costs and reduced ability for KTWD to deliver their contract water supplies for in-district use. This could occur from increased competition to convey water from the California Aqueduct to the FKC through the CVC for exchange with AEWSD and/or other Friant supplies. Additionally, there would be increased competition for exchanges with other Friant districts. There is a finite amount of exchange capacity within the Friant system, of which the Re-circulated Water deliveries could consume a large portion.

The competition for capacity could result in higher cost to KTWD in several ways. First, more of KTWD's water on the west side of the San Joaquin Valley could potentially have to be pumped all of the way from the California Aqueduct to the FKC and through the CVC which involves a total of six lift stations. In addition there would have to be up to 3 lift stations in the FKC.

Several banking projects own and operate groundwater extraction wells adjacent to the CVC. This water is often pumped directly into the CVC. This groundwater could potentially be exchanged for water in the California Aqueduct. Thus, KTWD would only be responsible for the CVC pumping charges from the point of groundwater introduction to the FKC and some of the pumping lifts along the CVC could be avoided. However, as competition for CVC capacity increases, more of the groundwater that is introduced into the CVC becomes unavailable for KTWD's exchange benefit and KTWD would have to pump more water from the California Aqueduct all of the way to the FKC.

8.7 - Delano-Earlimart Irrigation District

In above-normal water years, DEID has transferred surplus CVP SJR contract water to neighboring districts that share the same groundwater basin. This is done since a reduction in pumping in the neighboring districts has a beneficial impact on DEID groundwater levels. These transfers are performed primarily with Kern-Tulare Water District, and with Lower Tule River Irrigation District (LTRID) for the benefit of Pixley Irrigation District. These surplus waters may no longer be available, or may be reduced in quantity, as a result of diversion curtailments due to the Settlement. DEID has more recently entered into a banking agreement with a district with recharge and extraction

facilities along the CVC. When water is flowing in reverse in the FKC, these exchanges would still be feasible, but there may be less conveyance capacity to perform them in both the CVC and the FKC.

8.8 - Summary

The potential impacts to existing water management programs within each participating district were evaluated. Water management programs include existing agreements for water exchanges, transfers, sales, and banking. When Re-circulated Water is delivered, these existing programs could be impacted by increased competition for conveyance facilities, storage facilities, water supplies, and reduced water quality. Significant impacts could occur if exchange partners are expecting high quality CVP SJR water, but instead receive Re-circulated Water with SWP water quality.

The principal impact would likely occur from anticipated reverse flows in the southern portion of the FKC. This could inhibit some existing water management programs that rely on forward flow conditions in the FKC for many of the studied districts. Possible impacts to AEWSD could be significant given the reliance, in part, on their exchanges improving water quality to their exchange partner. Impacts to KTWD could also be significant. These impacts would include increased competition for CVC capacity and exchanges with other Friant districts, which could significantly increase water costs for KTWD.

The impacts to water management programs will depend on the timing and quantity of Re-circulated Water delivered each year. The timing is difficult to predict, and will vary each year. The quantity of Re-circulated Water will vary each year, but will average about 10 to15 percent of the studied districts' surface water supply.

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