Appendix M

Groundwater Blending Analysis

Appendix M - Groundwater Blending Analysis

M.1 All American Canal/ East Highline Canal Groundwater Augmentation & Blending, GEI TM August 21, 2009

M.2 Preliminary Evaluation of Substitution of Groundwater for Surface Water on Crop Water Needs. Davids Engineering. September 3, 2009.

Memo

To: Mike King, Tina Shields, Anisa Divine

From: Matt Zidar, Michael Conant

CC:

Date: August 21, 2006

Re: All American Canal/ East Highline Canal Groundwater Augmentation & Blending

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Purpose & Assumptions of Analysis

The purpose of this analysis was to obtain estimates of the changes in water quality for the All American Canal (AAC) and East Highline Canal (EHC) if the canal flow was augmented with East Mesa groundwater pumped either into the AAC or EHC. Using data from 2000-2007 obtained from Imperial Irrigation District, the average water quality for TDS on the AAC at station 60 was approximately 753 ppm. Conductivity was also reported in this documentation but TDS was used in this analysis due to its greater familiarity. TDS varied from 600 to 1050 ppm with 95% of samples falling between 640 and 920 ppm. Water quality at Station 60 was compared to canal flow at Drop 1 and it was determined that water quality was independent of flow (Figure 1). It is assumed that water quality changes little in conveyance along the canal and the average value of 753 ppm TDS was used for analysis at Mesa 5 and East Highline Drop 16, downstream of Station 60. Water quality for the groundwater to be pumped was unknown, so three potential representative values of 1000, 2000, and 3000 ppm TDS were analyzed. Potential contribution of the new groundwater was taken to be either 50,000 or 25,000 acre-feet, approximately 70 or 35 cfs if averaged over a year.

Flow's Affect on Change in Water Quality

Figure 2 shows how the water quality changes in any canal with any flow using the above assumptions. Larger initial flows from the canal would result in less change in water quality from the introduction of groundwater. Alternatively, small canal flows can be greatly influenced by the groundwater inflow. Using this graph, the expected resultant water quality could be obtained given a certain canal flow, groundwater TDS concentration and groundwater pumping rate. It can also be used to determine the minimum allowable flow if a maximum concentration level is established. As an example, if a maximum allowable TDS for the resultant water quality was 850, the minimum allowable initial canal flow could be determined for each of the 3 theoretical groundwater concentrations and each pumping rate. This is also outlined in figure 2.

Groundwater's Affect on AAC & East Highline Canals

To determine the potential change in water quality in the AAC and EHC, two flows were analyzed for each canal; one at the median flow to show a representative change, and one at the bottom 20th percentile flow to demonstrate a "worst case" scenario. These values were determined from data provided by Imperial Irrigation District and were representative of 2006-2008 for the AAC and from 2000-2008 for the EHC. Figures 3 and 4 show the resultant water quality for the AAC and EHC respectively. The AAC consistently has larger inflows and thus the change in water quality is substantially dampened. The figures can be used to evaluate the effects of different pumping rates at the assumed canal flows.

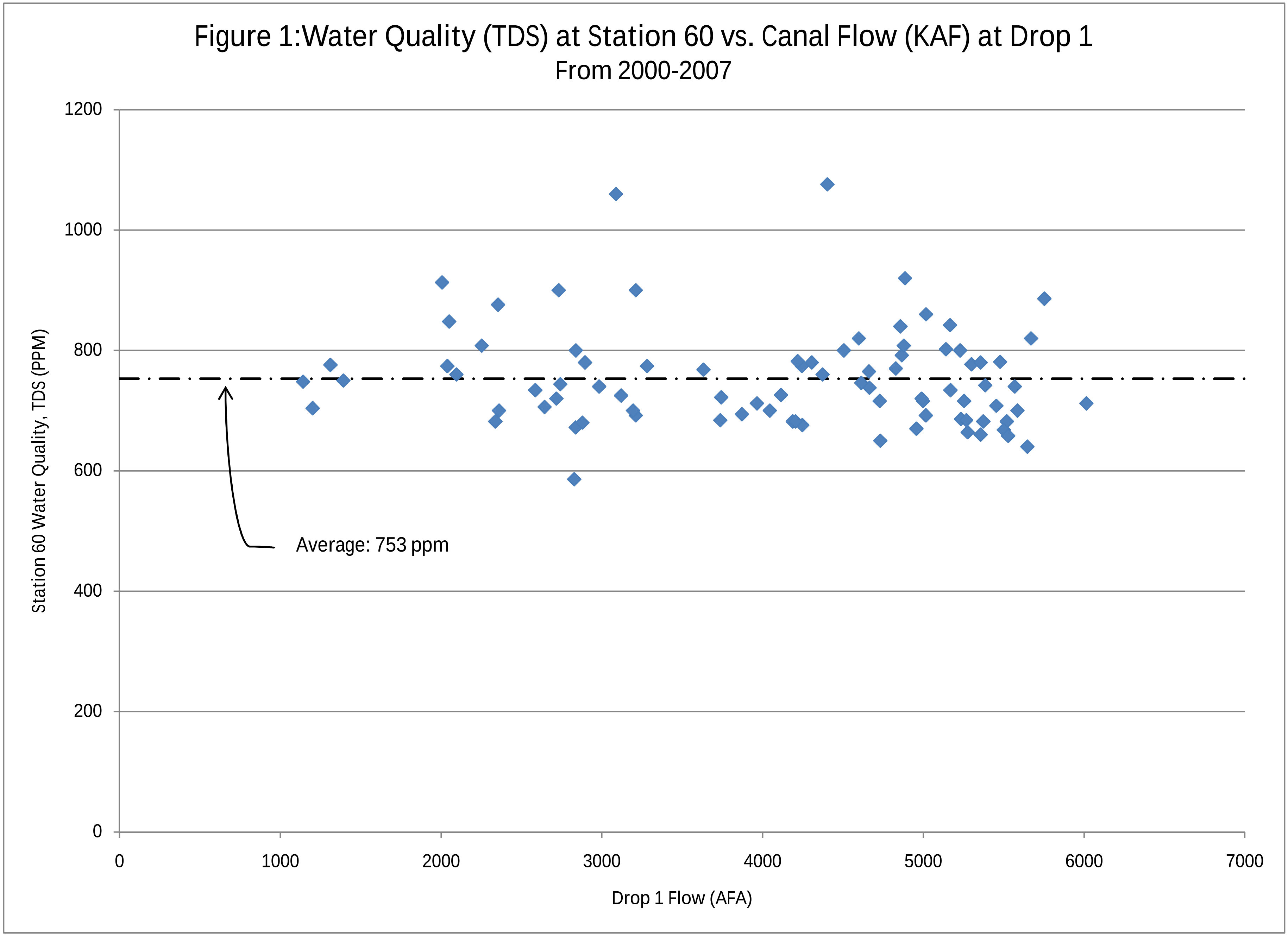
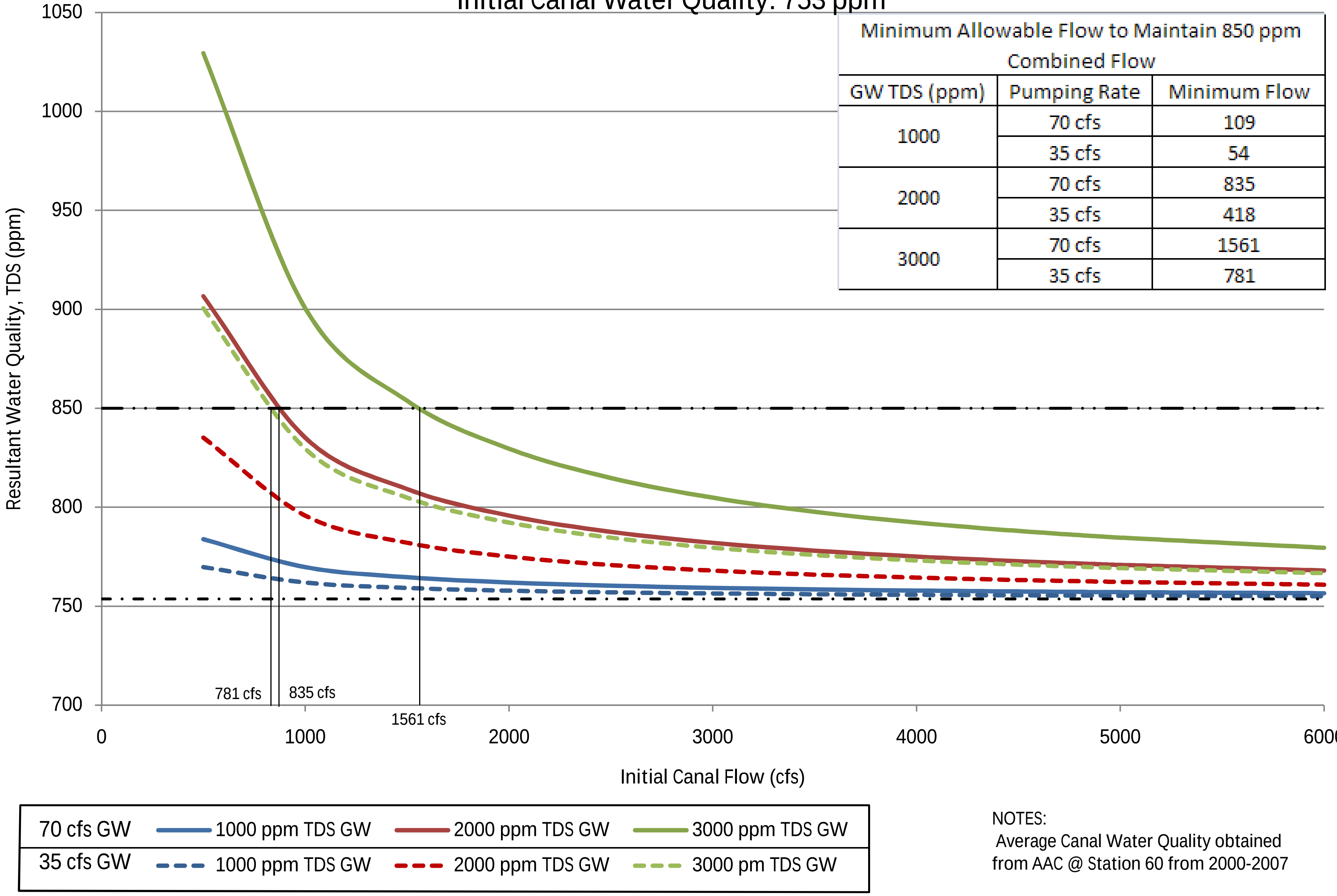


Figure 1:Water Quality (TDS) at Station 60 vs. Canal Flow (KAF) at Drop 1
From 2000-2007
Station 60 Water Quality, TDS (PPM)
Drop 1 Flow (AFA)
Average: 753 ppm
0
200
400
600
800
1000
1200
0
1000
2000
3000
4000
5000
6000
7000

Figure 2: Resultant Water Quality From GW Pumping at 35 and 70 cfs

Initial Canal Water Quality: 753 ppm



Minimum Allowable Flow to Maintain 850 ppm Combined Flow		
GW TDS (ppm)	Pumping Rate	Minimum Flow
1000	70 cfs	109
	35 cfs	54
2000	70 cfs	835
	35 cfs	418
3000	70 cfs	1561
	35 cfs	781

NOTES:
Average Canal Water Quality obtained from AAC @ Station 60 from 2000-2007

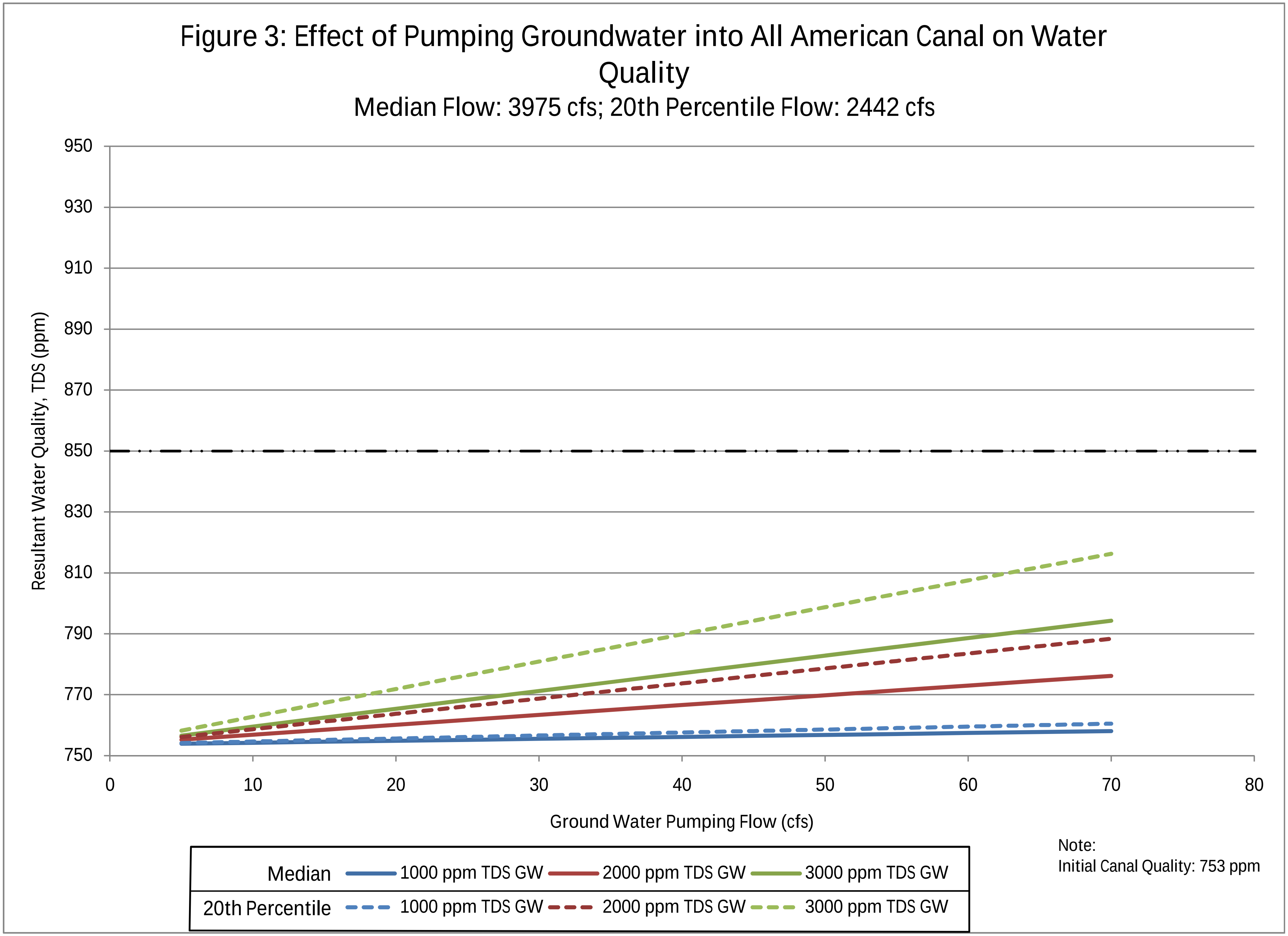


Figure 3: Effect of Pumping Groundwater into All American Canal on Water Quality
Median Flow: 3975 cfs; 20th Percentile Flow: 2442 cfs
950
930
910
890
870
850
830
810
790
770
750
Resultant Water Quality, TDS (ppm)
0
10
20
30
40
50
60
70
80
Ground Water Pumping Flow (cfs)
Median
1000 ppm TDS GW
2000 ppm TDS GW
3000 ppm TDS GW
20th Percentile
1000 ppm TDS GW
2000 ppm TDS GW
3000 ppm TDS GW
Note:
Initial Canal Quality: 753 ppm

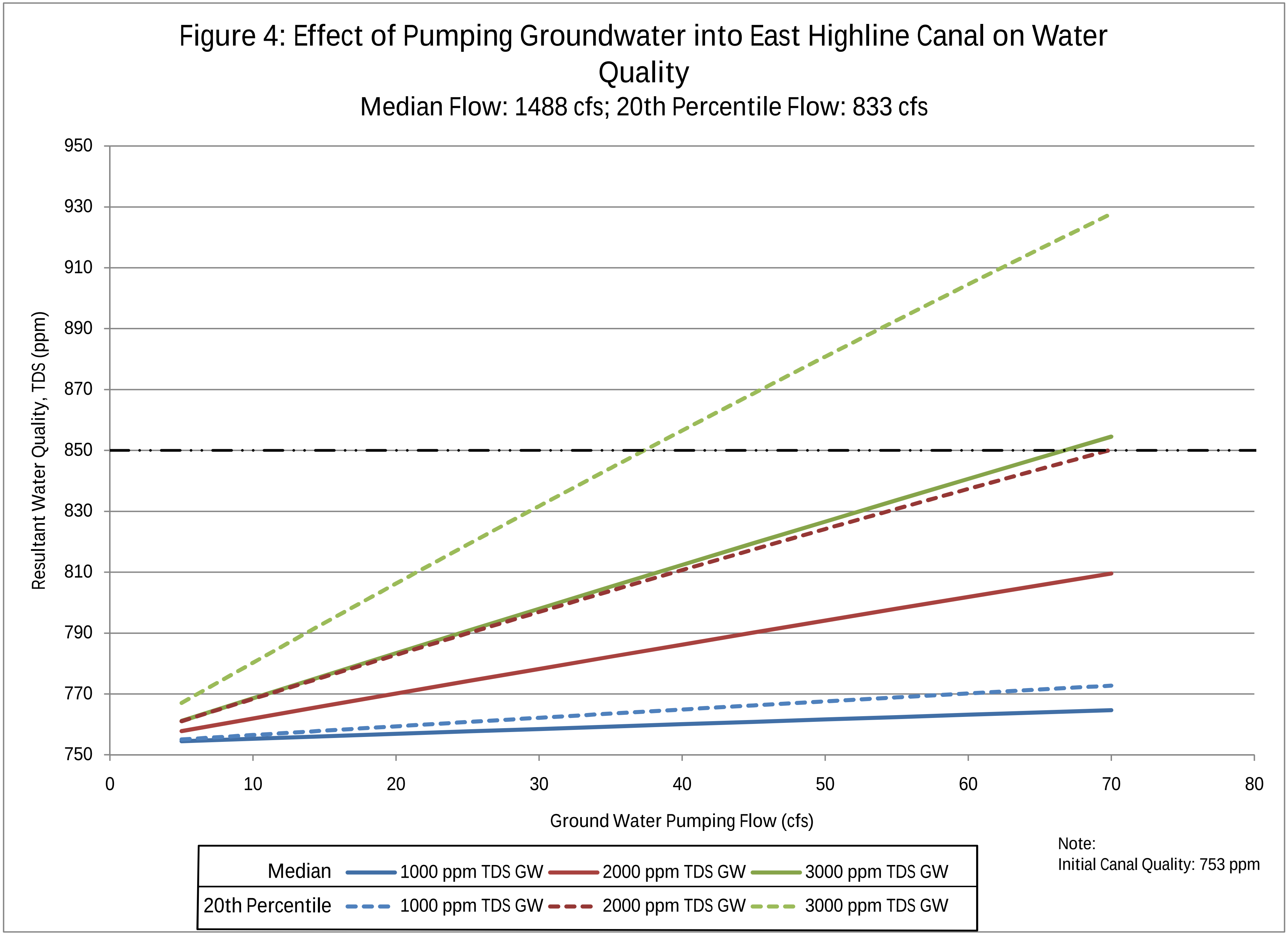


Figure 4: Effect of Pumping Groundwater into East Highline Canal on Water Quality
Median Flow: 1488 cfs; 20th Percentile Flow: 833 cfs
Resultant Water Quality, TDS (ppm)
950
930
910
890
870
850
830
810
790
770
750
0
10
20
30
40
50
60
70
80
Ground Water Pumping Flow (cfs)
Median
20th Percentile
1000 ppm TDS GW
2000 ppm TDS GW
3000 ppm TDS GW
Note:
Initial Canal Quality: 753 ppm

Specialists in Ag Water Management

Technical Memorandum

TO: Imperial Irrigation District
FROM: Davids Engineering, Inc.
DATE: September 3, 2009
SUBJECT: **Preliminary Evaluation of Substitution of Groundwater for Surface Water on Crop Water Needs**

Background and Objectives

Alternative additional water supplies are being investigated to satisfy growing M&I water demands within the Imperial Valley. One alternative water source being considered is groundwater pumped from wells within the East Mesa. One operational scenario associated with this source would be to blend groundwater with Colorado River water in the All American Canal and deliver the blended supply to IID customers. Because the salinity of the East Mesa groundwater is generally higher than that of Colorado River water, the effect of this operation would be an increase the salinity of water delivered to IID customers.

The purpose of this technical memorandum is to provide a preliminary, reconnaissance level evaluation of the potential impact of increased water salinity on crop water needs in the Imperial Irrigation District. For purposes of this evaluation, the impact of increasing salinity on the leaching requirement for primary IID crops is estimated, along with the cumulative impact on the volume of leaching required per unit of additional supply.

This analysis is based on the assumptions of GEI Consultants (2009) regarding the salinity of East Mesa groundwater and its blending with Colorado River water.

Methodology

The impact of alternative blending scenarios on LF_R for major IID crops is evaluated, along with the overall impact on District-wide irrigation requirements.

For a given crop, the required leaching fraction, LF_R, is given by the following relationship:

$$LF_R = \frac{EC_w}{5 \cdot EC_e - EC_w}, \qquad [1]$$

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where EC_w is the salinity of the irrigation water, and EC_e is the threshold soil salinity at which crop yield is affected (Ayers and Westcot, 1994). The required leaching fraction is the fraction of total applied water required for leaching, where the total applied water consists only of crop evapotranspiration and deep percolation.

For purposes of this analysis, the base salinity of Colorado River water is estimated to be 753 ppm TDS, or 1.18 dS/m (1 dS/m ≈ 640 ppm TDS). The threshold salinity for IID crops is estimated based on published values (Mass, 1990). The historical leaching fraction achieved by IID growers is estimated to be 0.19 based on the water balance prepared for the Efficiency Conservation Definite Plan.

The impact of groundwater blending on total crop water requirements is estimated based on the increase in leaching needed to maintain historical salinity levels. First, the impact of alternative blending ratios and groundwater salinity levels on the salinity of the blended irrigation water is evaluated. Then, the percent increase in crop water requirements across scenarios is evaluated. Finally, historical demands are multiplied by the percent increase in crop water requirements to estimate increased future demands to provide adequate leaching to maintain existing, average soil salinity levels.

Results

Based on the scenarios evaluated by GEI, the blending ratio (BR) of groundwater to surface water will vary from around 0.01 (AAC mean flow of 3975 cfs with 35 cfs GW pumping rate) to around 0.08 (EHL 20^{th} percentile flow of 833 cfs with 70 cfs GW pumping rate). Based on a range in BR of 0.00 to 0.10, the estimated blended water salinity for groundwater salinities of 1000 ppm, 2000 ppm, and 3000 ppm are provided in Table 1.

Table 1. Resultant Salinity for Varying Blending Ratios and Groundwater Salinities.

	Resultant EC_w for Varying GW Salinity (dS/m)		
Blending Ratio (GW/SW)	GW Salinity = 1000 ppm	GW Salinity = 2000 ppm	GW Salinity = 3000 ppm
0.00	1.18	1.18	1.18
0.01	1.18	1.20	1.21
0.02	1.18	1.21	1.25
0.03	1.19	1.23	1.28
0.04	1.19	1.25	1.31
0.05	1.19	1.27	1.34
0.06	1.20	1.29	1.38
0.07	1.20	1.30	1.41
0.08	1.21	1.32	1.44
0.09	1.21	1.34	1.47
0.10	1.21	1.35	1.50

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The impact of blending on crop specific leaching requirements for the top 10 IID crops (based on the 2008 IID crop survey) is presented for groundwater salinities of 1000 ppm, 2000 ppm, and 3000 ppm in Tables 2a, 2b, and 2c, respectively.

Table 2a. Impact of Blending Ratio on Required Leaching Fraction for Major IID Crops, Groundwater Salinity = 1000 ppm.

Rank	Crop	Acres (2008)	Threshold Salinity, ECe (dS/m)	LF_R for Varying Blending Ratios					
				0.00	0.02	0.04	0.06	0.08	0.10
1	Alfalfa	127,667	2.0	0.13	0.13	0.14	0.14	0.14	0.14
2	Wheat	111,050	4.5	0.06	0.06	0.06	0.06	0.06	0.06
3	Sudangrass	68,128	2.8	0.09	0.09	0.09	0.09	0.09	0.09
4	Bermudagrass	57,187	6.9	0.04	0.04	0.04	0.04	0.04	0.04
5	Lettuce	31,298	1.3	0.22	0.22	0.22	0.23	0.23	0.23
6	Sugarbeets	23,773	7.0	0.03	0.04	0.04	0.04	0.04	0.04
7	Carrots	14,962	1.0	0.31	0.31	0.31	0.32	0.32	0.32
8	Kliengrass	14,889	6.9	0.04	0.04	0.04	0.04	0.04	0.04
9	Broccoli	11,519	2.8	0.09	0.09	0.09	0.09	0.09	0.09
10	Onions	10,223	1.2	0.24	0.25	0.25	0.25	0.25	0.25

Table 2b. Impact of Blending Ratio on Required Leaching Fraction for Major IID Crops, Groundwater Salinity = 2000 ppm.

Rank	Crop	Acres (2008)	Threshold Salinity, ECe (dS/m)	LF_R for Varying Blending Ratios					
				0.00	0.02	0.04	0.06	0.08	0.10
1	Alfalfa	127,667	2.0	0.13	0.14	0.14	0.15	0.15	0.16
2	Wheat	111,050	4.5	0.06	0.06	0.06	0.06	0.06	0.06
3	Sudangrass	68,128	2.8	0.09	0.10	0.10	0.10	0.10	0.11
4	Bermudagrass	57,187	6.9	0.04	0.04	0.04	0.04	0.04	0.04
5	Lettuce	31,298	1.3	0.22	0.23	0.24	0.25	0.26	0.26
6	Sugarbeets	23,773	7.0	0.03	0.04	0.04	0.04	0.04	0.04
7	Carrots	14,962	1.0	0.31	0.32	0.33	0.35	0.36	0.37
8	Kliengrass	14,889	6.9	0.04	0.04	0.04	0.04	0.04	0.04
9	Broccoli	11,519	2.8	0.09	0.10	0.10	0.10	0.10	0.11
10	Onions	10,223	1.2	0.24	0.25	0.26	0.27	0.28	0.29

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Table 2c. Impact of Blending Ratio on Required Leaching Fraction for Major IID Crops, Groundwater Salinity = 3000 ppm.

			Threshold Salinity,	LF_R for Varying Blending Ratios					
Rank	Crop	Acres (2008)	ECe (dS/m)	0.00	0.02	0.04	0.06	0.08	0.10
1	Alfalfa	127,667	2.0	0.13	0.14	0.15	0.16	0.17	0.18
2	Wheat	111,050	4.5	0.06	0.06	0.06	0.07	0.07	0.07
3	Sudangrass	68,128	2.8	0.09	0.10	0.10	0.11	0.11	0.12
4	Bermudagrass	57,187	6.9	0.04	0.04	0.04	0.04	0.04	0.05
5	Lettuce	31,298	1.3	0.22	0.24	0.25	0.27	0.28	0.30
6	Sugarbeets	23,773	7.0	0.03	0.04	0.04	0.04	0.04	0.04
7	Carrots	14,962	1.0	0.31	0.33	0.36	0.38	0.40	0.43
8	Kliengrass	14,889	6.9	0.04	0.04	0.04	0.04	0.04	0.05
9	Broccoli	11,519	2.8	0.09	0.10	0.10	0.11	0.11	0.12
10	Onions	10,223	1.2	0.24	0.26	0.28	0.30	0.31	0.33

As shown in Table 2, blending of saline groundwater with canal water results in an increase in crop water requirements to satisfy leaching. The increase in total water requirements using blended water relative to existing water supplies is greatest for salt sensitive crops due to a relatively large percentage of total water requirements being needed to satisfy the leaching requirement.

The increase in total crop water requirements resulting from increased irrigation water salinity can be estimated based on a threshold salinity target for the bottom of the crop root zone. In recent history, the average leaching fraction within IID has been approximately 0.19, as described by Keller-Bliesner Engineering (Efficiency Conservation Definite Plan, Appendix 1.B). For purposes of this analysis, it is assumed that the threshold salinity for the bottom of the crop root zone of 6.20 dS/m, based on irrigation water salinity of 1.18 dS/m and historical leaching fraction of 0.19.

The leaching fraction needed to maintain target salinity at the bottom of the root zone is given by:

$$LF = \frac{EC_w}{EC_{br}}, \qquad [2]$$

where LF is the leaching fraction, EC_w is the salinity of the irrigation water, and EC_{br} is the salinity threshold at the bottom of the root zone.

Total crop water requirements to satisfy crop ET and leaching are given by:

$$AW = \frac{ET}{1 - LF}, \qquad [3]$$

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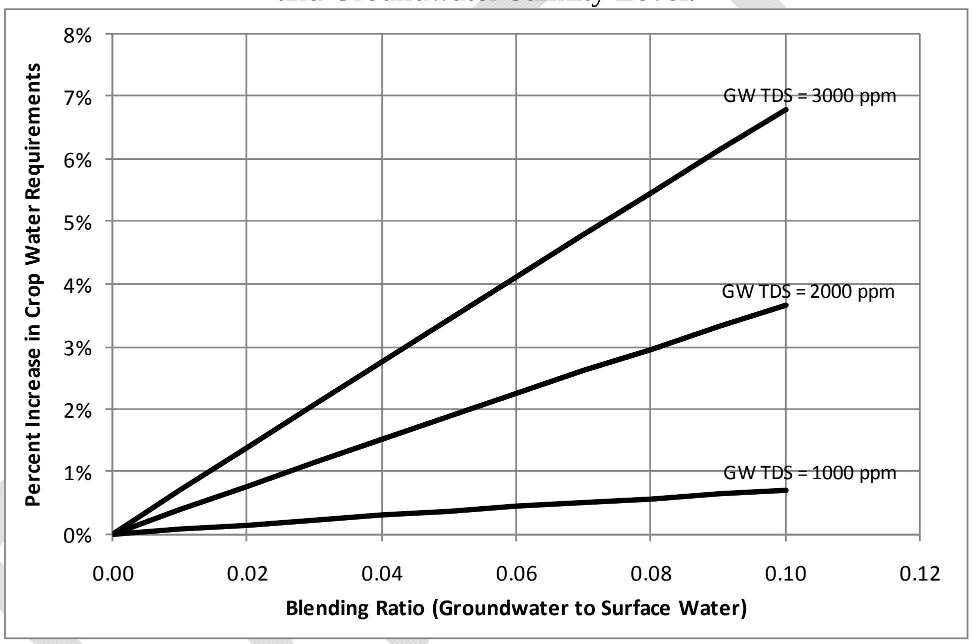
Thus, for any given amount of crop ET, the percent increase in crop water requirements is given by:

$$\% \, Increase = \frac{1 - LF_{cw}}{1 - LF_{bw}} - 1, \quad [4]$$

where LF_{bw} is the leaching fraction for blended water calculated using Equation 2 based on values from Table 1 and EC_{br} = 6.20 dS/m, and LF_{cw} is the historical leaching fraction of 0.19. The increase in crop water requirements for alternative blending ratios and groundwater salinity levels is presented in Figure 1.

Figure 1. Percent Increase in Crop Water Requirements with Varying Blending Ratio and Groundwater Salinity Level.



Based on median flows in the East Highline and All American canals of 1488 cfs and 3975 cfs, respectively, as reported by GEI (2009), the additional groundwater pumping needs to satisfy increased irrigation water demands for varying levels of pumping to offset M&I deliveries is provided in Table 3. The median flows were multiplied by a factor of 0.89 to estimate on-farm delivery volumes based on the results of the ECDP IID water balance. This yielded an annual on-farm delivery volume estimate of 954,800 ac-ft for the East Highline and 2,550,700 ac-ft for the All American.

An adjustment factor, expressed as the ratio of total pumping needs to M&I deliveries based on Table 3 was calculated for each hypothetical groundwater salinity level. These values are 1.07, 1.52, and 2.62 for groundwater with salinity of 1000 ppm, 2000 ppm, or 3000 ppm, respectively. These values could be used to estimate total pumping needs to support design of the well field for any given level of M&I deliveries. For example, at a

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groundwater salinity of 2000 ppm, to provide 10,000 acre-feet for M&I use would require total pumping of 15,200 acre-feet to account for increased crop water needs.

Table 3. Additional Pumping Needed to Satisfy Increased On-Farm Demands with Varying Total Pumping and Groundwater Salinity.

Total Groundwater Pumping Volume (ac-ft)	Additional Pumping to Satisfy Increased On-Farm Demands with Varying Groundwater Salinity (ac-ft)			Net Increase in Supply (ac-ft)		
	1000 ppm	2000 ppm	3000 ppm	1000 ppm	2000 ppm	3000 ppm
1,000	68	344	620	932	656	380
5,000	340	1,717	3,096	4,660	3,283	1,904
10,000	679	3,431	6,190	9,321	6,569	3,810
15,000	1,017	5,142	9,280	13,983	9,858	5,720
20,000	1,354	6,848	12,366	18,646	13,152	7,634
25,000	1,689	8,551	15,450	23,311	16,449	9,550
30,000	2,024	10,250	18,530	27,976	19,750	11,470
40,000	2,690	13,638	24,681	37,310	26,362	15,319
50,000	3,352	17,012	30,820	46,648	32,988	19,180
60,000	4,009	20,372	36,945	55,991	39,628	23,055
70,000	4,663	23,717	43,058	65,337	46,283	26,942
80,000	5,313	27,049	49,158	74,687	52,951	30,842
90,000	5,958	30,366	55,245	84,042	59,634	34,755
100,000	6,599	33,670	61,320	93,401	66,330	38,680
110,000	7,237	36,960	67,383	102,763	73,040	42,617
120,000	7,870	40,237	73,432	112,130	79,763	46,568
130,000	8,500	43,500	79,470	121,500	86,500	50,530
140,000	9,126	46,749	85,495	130,874	93,251	54,505
150,000	9,748	49,985	91,507	140,252	100,015	58,493

Conclusions

In general, the increase in total crop water requirements for a given groundwater salinity, blending ratio, and crop are small. It is likely that adjustments to irrigation and other management practices in response to small increases in water salinity will be small; however, over time and in aggregate it is anticipated that growers will respond by applying additional irrigation water to maintain salt balance in the root zone in order to maintain crop production.

Increased leaching requirements can be expressed relative to groundwater pumping volumes offsetting M&I deliveries and range from approximately 7% of the M&I delivery volume to 162% of the delivery volume over the range of groundwater salinity levels evaluated. These expected future on-farm demands should be considered in the evaluation and design of well fields to increase overall water supply.

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