Expert Report

of

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on

Friant Service Area

Reasonableness of Surface Water Use, Annual Gross Groundwater Pumping Requirement, and Estimated Increased Energy Use under the Spring Run Scenario by 2025

August 18, 2005

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Assignment

I was asked to provide technical information on the following topics regarding irrigation water diverted from the San Joaquin River into the Friant-Kern Canal and the Madera Canal:

1. The reasonableness of use of that diverted water.
2. An estimate of the annual groundwater pumping requirements.
3. An estimate of the increased energy use by year 2025 under the Spring Run release scenario.

This report contains my conclusions related to these topics.

Topic #1 – Reasonable and Beneficial Use of Diverted Water

The physical data show that Friant water is used efficiently for agricultural irrigation. This can be determined through either a detailed examination of crop water usage, or a big-picture look at the entire system. The big-picture reasoning is this: Within the Friant service area, there are fairly extensive areas of groundwater overdraft, and little/no irrigation water leaving the area as surface flow. This indicates that the water that is applied within the service area, even when combined with any natural groundwater supplies, is insufficient.

Key points that prove the Friant water is reasonably and efficiently used include:

1. **Table 1** shows that the actual crop evapotranspiration (ET) needs are greater than the total sum of the net precipitation, plus all surface deliveries (Friant and other). In other words, there is not enough water available for the present level of development. **Appendix A** contains a summary of supporting data and procedures used to compute the Net Groundwater Extraction.

Table 1. Summary of Water Balance for the Friant service area

Total Irrigated Acreage	1999-2003 average total ET of *irrigation water* (including groundwater) by crops (AF)	1999-2003 Average Surface Water Supplies from Sources other than Friant (AF)	1999-2003 Average Surface Water Supplies from Friant (AF)	**Estimated Average Annual Net Groundwater Extraction (AF)**
831,229	1,826,753	680,707	993,421	**152,624**

2. Canal seepage and on-farm over-irrigation within the Friant service area do not result in a loss of water to the service area boundaries because of extensive groundwater pumping by individual farmers in most of the districts. **Table 2** indicates the extent of farm wells within the service area. The true extent of wells is understated for some districts here, because within the project boundaries some wells are also owned and operated by various irrigation districts, plus there are numerous domestic wells and usage by cities.

Table 2. Farm wells within various districts in the Friant service area

District	% of farms with wells	District	% of farms with wells
Arvin-Edison WSD	50	Orange Cove Irrigation District	60
Chowchilla Water District	100	Porterville Irrigation Dist	90
Delano-Earlimart ID	100	Saucelito Irrigation District	100
Exeter Irrigation District	85	Shafter-Wasco Irrigation District	90
Fresno Irrigation District	100	Stone Corral Irrigation Dist	80
Ivanhoe Irrigation District	100	Tea Pot Dome Water District	80
Lindmore Irrigation District	98	Madera Irrigation District	100
Lindsay-Strathmore ID	33	Southern San Joaquin MUD	100
Lower Tule River ID	100	Tulare Irrigation District	100

Within some of the irrigation districts (e.g., Lindsay-Strathmore and Orange Cove), there are areas with no or little usable groundwater supply.

3. What the data above do not show is another very important aspect of Friant water destination: the reliance of others on this limited water supply. Within the project area, most of the cities, towns, industries, and houses outside of the cities rely on groundwater supplies. Those groundwater supplies are recharged by the Friant system.

4. Groundwater overdraft is well documented in several areas within the service area – showing that more groundwater is being used than is re-supplied.

5. There are little or no surface drainage flows (except for flood events) leaving the districts. The area of Madera ID and Chowchilla ID has well-documented groundwater overdraft, and surface canal-end spills from the district boundaries have been almost totally eliminated.

6. Any groundwater that does flow laterally out of the project boundaries is captured by downhill farmers and irrigation districts. An example is Alpaugh ID, which depends entirely on well water.

The above points demonstrate that the Friant system is providing beneficially used water that is not available from other sources. From a practical standpoint, the conclusion is that any reduction in irrigation water deliveries from the Friant system will result in an accelerated decline in groundwater levels, reduction in cropped acreage in some areas in the near term, and reduction in cropped acreage throughout the project over time.

Topic #2 – Gross Irrigation Well Pumping

Estimates of pumping economics require an estimate of the annual volumes (acre-feet) of irrigation water that are pumped by farmers in the Friant service area.

It is important to note two points about these estimates:

1. These gross <u>well pumping volumes</u> are ***<u>not</u>*** equivalent to the <u>net groundwater extraction volumes</u> of Topic #1. Because there are inefficiencies associated with the application of the well pumping volume, this pumping volume is greater than the net extraction from the aquifer (Burt, 1999; Solomon and Burt, 1998; Burt and Styles, 2004).

2. There are several differences between the methodologies used to compute the two numbers. **Appendix B** describes the methodology used to estimate well pumping volumes, and discusses the differences between the Topic 1 and Topic 2 computations.

Table 3 summarizes the estimated gross irrigation well pumping by year and by irrigation district, for a range of years. This pumping is my best estimate of what was pumped in the each Friant district during the period 1987-2003. The description of how these numbers were derived is set forth in Appendix B.

Table 3. Estimated annual gross groundwater pumping (gross Acre-feet) in the Friant service area.

District	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Arvin Edison WSD	173,295	168,499	170,785	226,837	231,121	268,595	174,424	271,791	132,229	174,609	133,602	102,342	162,000	162,794	254,962	232,878	183,680
Delano-Earlimart Irrigation District	49,626	48,670	46,841	73,119	35,686	65,068	1,552	75,267	9,476	16,969	1,511	3,364	23,714	17,331	30,885	31,273	23,402
Shafter-Wasco Irrigation District	75,018	77,147	66,817	87,832	68,754	71,359	29,627	85,439	33,232	52,729	44,929	51,738	57,464	54,171	54,105	67,177	47,365
Southern San Joaquin MUD	90,862	91,285	82,581	110,737	87,537	93,240	51,463	76,821	43,338	62,831	44,853	34,433	59,767	42,106	50,945	60,650	37,971
Saucelito Irrigation District	23,185	23,453	23,411	31,942	24,138	25,505	43,098	22,699	0	333	4,714	0	7,376	1,356	23,294	23,983	18,623
Tea Pot Dome Water District	2,349	3,966	2,009	4,534	3,840	1,303	1,416	1,426	323	1,909	1,488	466	302	2,239	2,115	2,346	2,907
Terra Bella Irrigation District	13,234	13,194	10,984	16,171	19,312	11,850	10,816	10,775	11,177	12,799	11,362	3,722	17,921	15,966	12,031	10,083	12,430
Lower Tule River Irrigation District	204,816	189,886	158,178	240,772	203,626	219,100	32,615	180,829	0	91,146	59,742	0	119,121	85,455	206,957	200,232	138,889
Porterville Irrigation District	29,649	26,279	30,740	37,274	35,431	27,648	25,627	20,473	19,064	22,288	21,867	15,368	26,048	22,187	26,350	25,288	26,443
Tulare Irrigation District	205,743	160,844	171,063	220,658	162,978	166,920	0	134,318	0	17,469	16,433	0	72,751	28,562	134,371	117,218	59,693
Exeter Irrigation District	26,655	27,577	24,229	32,897	28,034	23,826	15,017	24,055	13,024	15,597	18,453	13,237	20,785	21,541	21,073	22,175	23,279
Ivanhoe Irrigation District	18,213	20,684	17,139	26,291	20,361	21,262	7,927	20,211	8,626	13,952	15,246	9,112	16,597	18,289	16,824	18,181	15,496
Lindmore Irrigation District	45,102	39,367	39,324	59,985	42,937	37,072	25,958	42,231	22,561	25,428	31,568	20,713	35,203	37,819	37,366	40,332	33,142
Lindsay-Strathmore ID	12,416	13,407	9,163	14,213	19,104	10,094	12,803	14,112	10,597	15,604	9,459	8,828	12,606	15,881	13,326	13,601	19,252
Lewis Creek Water District	1,057	954	1,052	1,316	1,122	939	844	911	440	1,029	31	1,369	895	1,913	2,301	1,160	1,424
Orange Cove Irrigation District	43,152	43,990	39,751	54,738	45,477	36,289	30,456	45,261	35,762	44,226	42,874	25,665	44,136	49,093	42,903	42,918	44,902
Stone Corral Irrigation District	10,267	8,159	6,922	9,909	9,152	8,886	8,490	10,127	8,040	9,129	7,664	8,153	11,462	10,650	9,800	8,896	9,267
Fresno Irrigation District	225,022	171,012	202,564	317,719	230,396	194,912	0	136,509	176,314	68,395	0	0	33,729	41,752	176,467	79,548	34,879
Garfield Irrigation District	0	829	0	0	1,056	0	0	0	1,186	0	0	1,319	0	0	44	0	158
International ID	1,041	1,052	708	1,131	1,012	1,056	328	454	422	0	492	0	670	690	431	371	550
Chowchilla Water District	102,493	123,854	145,573	159,925	132,045	158,684	45,507	121,022	68,911	79,941	75,141	63,652	76,308	77,632	116,579	149,399	127,277
Madera Irrigation District	221,761	203,542	203,927	251,936	198,329	211,468	37,960	189,020	71,875	96,883	120,782	74,959	155,105	145,597	212,958	211,445	191,482
Gravelly Ford Water District	25,323	23,270	24,204	26,475	24,785	23,267	11,738	22,523	9,368	14,483	16,195	13,559	20,814	19,847	22,199	18,105	17,749
Total	1,600,282	1,480,918	1,477,967	2,006,410	1,626,234	1,678,344	567,665	1,506,275	675,963	837,749	678,406	451,999	974,775	872,871	1,468,285	1,377,259	1,070,259

Topic #3 – Increased Groundwater Pumping Energy Requirement

Table 4 shows the annual increase in groundwater pumping energy requirements for a possible release scenario after 20 years. For this analysis the gross groundwater pumping shown in **Table 4** is the average gross groundwater pumping from 1999-2003 shown in **Table 3**. **Appendix C** describes the methodology used to determine pumping energy requirements.

The increase in groundwater extraction is equal to the average year reduction in surface water deliveries under the Spring Run Release scenario as modeled by Daniel Steiner.

The estimates in **Table 4** do not include additional pumping energy requirements for areas outside the Friant districts that will be impacted by the lower groundwater levels.

Table 4. Increased groundwater pumping energy requirement after 20 years of average surface water reduction under the Spring Run release scenario.

	A	B	C	D	(D*B)+[A*(D-C)]
	1999-2003	Spring Run	Current (2003)	Spring Run	Spring Run
	Average Gross Groundwater Extraction	Increase in Groundwater Extraction	Groundwater Pumping Requirement	Groundwater Pumping Requirement	Increased Energy Requirement after 20 Years
District	AF/Year	AF/Year	kWh/AF	kWh/AF	kWh/Year
ARVIN-EDISON W.S.D.	199,263	53,469	810	1,616	247,186,119
DELANO-EARLIMART I.D.	25,321	31,924	367	812	37,159,106
SHAFTER-WASCO I.D.	56,056	15,458	646	1,164	47,020,890
SOUTHERN SAN JOAQUIN MUD	50,288	26,051	358	582	26,441,143
SAUCELITO I.D.	14,926	8,904	364	764	12,772,397
TEA POT DOME W.D.	1,982	1,447	325	718	1,819,559
TERRA BELLA I.D.	13,686	5,594	295	684	9,150,760
LOWER TULE RIVER I.D.	150,131	46,743	344	759	97,800,918
PORTERVILLE I.D.	25,263	7,490	139	502	12,947,039
TULARE I.D.	82,519	26,485	315	762	57,027,286
EXETER I.D.	21,771	5,008	168	409	7,295,413
IVANHOE I.D.	17,077	2,645	188	355	3,787,612
LINDMORE I.D.	36,773	9,595	158	521	18,312,619
LINDSAY-STRATHMORE I.D.	14,933	5,305	139	252	3,032,992
LEWIS CREEK W.D.	1,539	280	129	241	239,544
ORANGE COVE I.D.	44,790	7,562	100	343	13,502,952
STONE CORRAL I.D.	10,015	1,929	110	355	3,138,829
*FRESNO I.D.**	*73,275*	*11,010*	*180*	*180*	*1,983,929*
*GARFIELD W.D.**	*40*	*675*	*321*	*321*	*216,711*
*INTERNATIONAL W.D.**	*542*	*231*	*124*	*124*	*28,678*
CHOWCHILLA W.D.	109,439	34,097	302	766	76,891,476
MADERA I.D.	183,317	43,701	302	598	80,331,219
GRAVELLY FORD W.D.	19,743	2,055	283	575	6,941,298
Total	**1,152,690**	**347,659**			**765,028,490**

**The change in groundwater level for Fresno ID, Garfield WD, and International WD was assumed to be zero after 20 years because the increase in groundwater extraction was small compared to the combined service area.*

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Appendix A – Topic 1
Net Groundwater Extraction in the Friant Service Area

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Net Groundwater Extraction in the Friant Service Area

Importance

The net groundwater extraction is a key indicator of project irrigation efficiency in a conjunctive use project. The importance of this computation arises because the Friant service area extensively practices conjunctive use – the reuse of groundwater as a supplement to first-time use of surface water supplies.

Because the service area is predominately a conjunctive use region, on-farm irrigation efficiencies and conveyance seepage losses are not considered mathematically when computing the project efficiency. Rather, the computation emphasizes the flows into and out of the 3-Dimensional spatial boundaries of the project, and the change in aquifer storage (Burt et al., 1997). In the Friant service area, the best indicator available for this type of estimate is the net groundwater extraction.

The collection of data for the Friant service area has includes published information on crop acreage by irrigation district and deliveries to each district. Descriptions of how the data were obtained and processed are in the following sections. The years included in the study are from 1999-2003.

Selection of Time Period

The five years of detailed study selected were chosen because they represent recent conditions. One could argue that over the complete history of the Friant project, the surface deliveries during this five-year period are somewhat lower than the average – and therefore the groundwater pumping is over-estimated. However, a counter-argument is that with global warming the recent period is more indicative of future water consumption. In either case, the final answer – that the Friant water is used with a high irrigation efficiency – is the same.

Irrigation Efficiency

The Irrigation Efficiency of the Friant Water is above 90% – which is unusually high for irrigation projects in the western U.S.

Irrigation Efficiency (IE) is defined (Burt et al., 1997) as:

$$IE = \frac{\text{Irrigation Water Beneficially Used}}{\text{Irrigation Water Applied - Change in Aquifer Storage}} \times 100$$

For the purposes of this project, considerations of "beneficial uses" were confined to evapotranspiration of irrigation water (ETirr). This understates the total beneficial uses somewhat because it ignores beneficial uses associated with Leaching Requirements (LR – to maintain a desirable salt balance in the crop root zone) and some climate control. However, the irrigation water in the Friant service area is generally very pure, so the Leaching Requirement is close to zero. Climate control use is also relatively minor. Given the fact that it is difficult to accurately estimate project-level ETirr values closer than 10%, there is no point in finessing the numbers with small leaching requirement and climate control quantities.

For a project-wide analysis of IE, the spatial boundaries of concern are the Friant service area itself, which include the surface area of the irrigation districts and extend down into the groundwater aquifer. The on-farm IE values, although computed with the same formula, use different values and are therefore different than the project-wide IE.

Net Groundwater Extraction

The estimated average ***net*** groundwater extraction is computed as the difference between the evapotranspiration of irrigation water (ETirr) and the surface irrigation water imported by Friant and local sources. Note that ETirr is <u>not</u> the total evapotranspiration of the crops (ETc).

ETirr = (Total annual ETc requirement) – (ET of precipitation)

ETirr only has two ultimate sources of water on a project level:

1. *Surface water that comes into the service area.* It is assumed that all of the surface irrigation water deliveries to the service area were eventually put to beneficial use (ETirr) – either during the first-time application of irrigation water, or eventually by having deep percolation go into the aquifer and be recovered through conjunctive use. Conveyance efficiency and on-farm irrigation efficiency are not considered in the computations because those internal "losses" of irrigation water are eventually recycled internally through conjunctive use.
2. *Net groundwater extraction*, which by definition does not include any recycled surface irrigation water (that water is included in (1) above). These groundwater supplies either come from lateral subsurface inflow, natural recharge from rivers/streams, or depletion of the groundwater.

ETirr = (Surface irrigation water deliveries to the service area) + (Net groundwater extraction)

Re-arranging the equation above,

Net groundwater extraction = (ETirr) – (Irrigation water deliveries to the service area)

Crop Acreage

The crop acreage for each district was obtained from irrigation district water management plans. The acreage values include double cropping to provide a proper accounting of the ET. **Table A1** summarizes the district irrigated crop acreage.

Table A1. Friant Service Area Total Irrigated Acreage by Irrigation District

District	Total Irrigated Acreage
	Acres
ARVIN-EDISON W.S.D.	110,754
DELANO-EARLIMART I.D.	47,892
SHAFTER-WASCO I.D.	30,531
SOUTHERN SAN JOAQUIN MUD	43,589
SAUCELITO I.D.	17,001
TEA POT DOME W.D.	2,947
TERRA BELLA I.D.	9,976
LOWER TULE RIVER I.D.	87,865
PORTERVILLE I.D.	12,848
TULARE I.D.	60,702
EXETER I.D.	11,947
IVANHOE I.D.	10,269
LINDMORE I.D.	23,984
LINDSAY-STRATHMORE I.D.	11,998
LEWIS CREEK W.D.	737
ORANGE COVE I.D.	24,837
STONE CORRAL I.D.	6,049
FRESNO I.D.	139,763
GARFIELD W.D.	1,000
INTERNATIONAL W.D.	655
CHOWCHILLA W.D.	65,724
MADERA I.D.	102,660
GRAVELLY FORD W.D.	7,503

Total	**831,229**

Table A2 summarizes acreage for crop groups throughout the Friant service area during the five-year period that was examined.

Table A2. 1999-2003 average acreage by crop grouping in the Friant service area

Crop Group	Acreage
ALFALFA	89,032
CITRUS	106,645
CORN	58,506
COTTON	59,015
FIELD CROPS	9,963
FRUITS	51,999
GRAPES	235,679
NURSERY	4,243
NUTS	124,179
SMALL GRAINS	50,597
VEGETABLES	41,372
Total	**831,229**

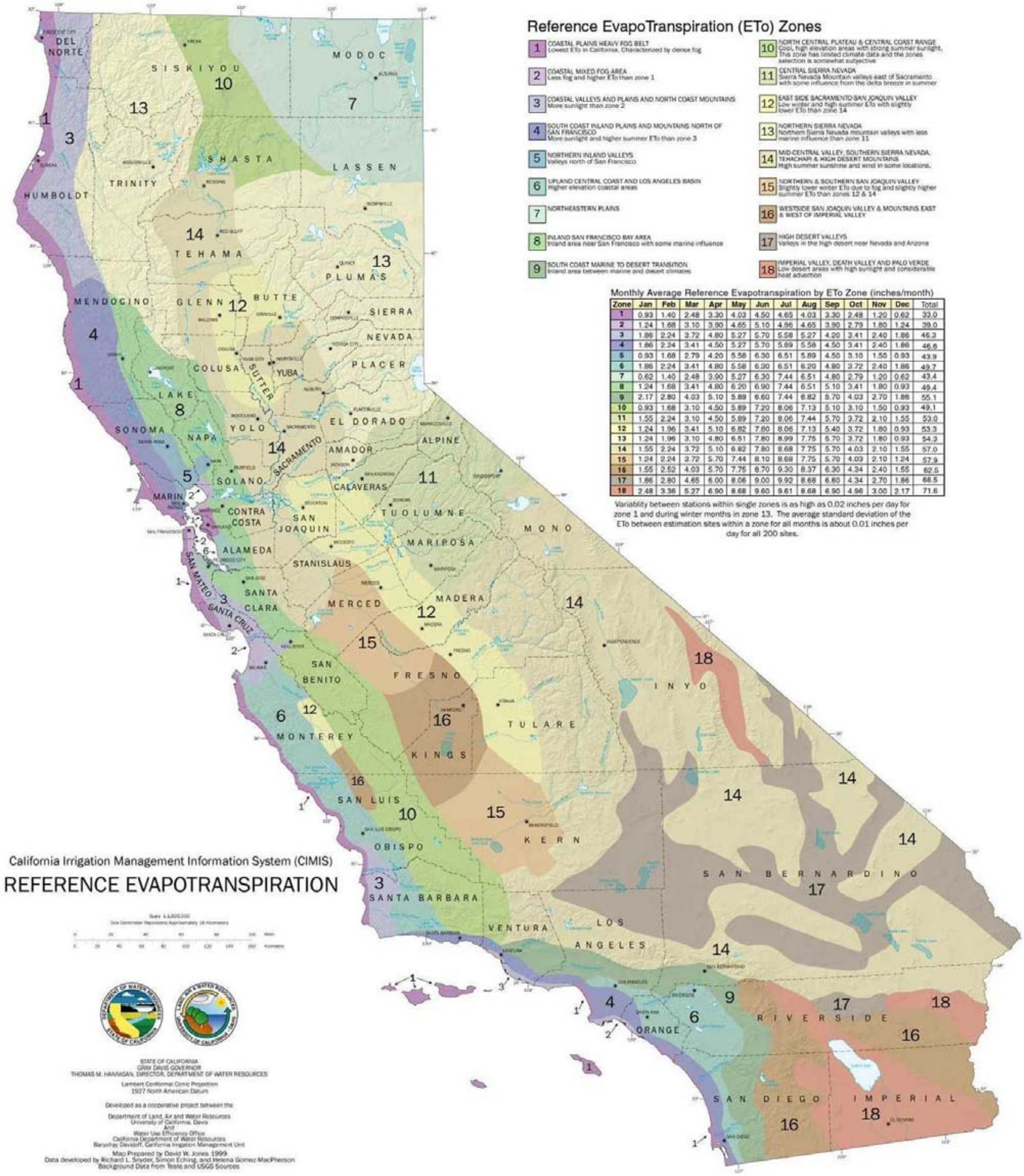
Evapotranspiration of Irrigation Water (ETirr)

The evapotranspiration of irrigation water (ETirr) was calculated for regions throughout California in the "Evaporation from Irrigated Agricultural Land in California" study conducted by ITRC in 2000. The regional breakdown was based on the DWR Reference Evapotranspiration (ETo) Zone Map shown in **Figure A1**. Friant service area encompasses two ETo zones (zones 12 and 15).

ETirr is crop irrigation water requirement – as opposed to total crop evapotranspiration (ETc or ETc+s), which is the total crop water requirement including effective precipitation. This is also different from various definitions of "consumptive use" – which may or may not include ET that occurs outside of the crop growing season. Furthermore, for Topic 1 in this project, the ETirr is de-rated to account for bare spots and decreased vigor, accounting for actual field conditions.

Evapotranspiration varies by crop, irrigation method, soil type, management, etc. For the "Evaporation from Irrigated Agriculture" study commissioned by CALFED, ITRC modeled ETc using the FAO 56 dual crop coefficient method (Allen et al, 1998). Crop stress due to improper irrigation timing was incorporated into the model, as well as the de-rating for bare spots and decreased vigor mentioned above. More details on the ITRC - FAO 56 model and its inputs can be found in the report "Evaporation from Irrigated Agricultural Land in California" (http://www.itrc.org/reports/evapca/evaporationca.htm), and in the references Mutziger et al (2005) and Allen et al (2005).

For this study, grass reference evapotranspiration (ETo) weather data from two CIMIS stations, Shafter (station #5) and Visalia (station #33), was obtained for the study years. Precipitation data from NOAA stations in Lindmore and Shafter was gathered for the study period because of errors in the CIMIS precipitation data. This data was used in the ITRC-FAO 56 model to calculate ETirr for the Friant districts. Data from the Visalia/Lindmore stations was used with the crop input data for Zone 12. Data from the Shafter stations was used with the crop input data for Zone 15. **Table A3** shows the ETirr data adjusted for bare spots and decreased vigor for ETo zones 12 and 15.



Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.62	33.0
2	1.24	1.68	3.10	3.90	4.65	5.10	4.96	4.65	3.90	2.79	1.80	1.24	39.0
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	4.50	3.41	2.40	1.86	46.6
5	0.93	1.68	2.79	4.20	5.58	6.30	6.51	5.89	4.50	3.10	1.50	0.93	43.9
6	1.86	2.24	3.41	4.80	5.58	6.30	6.51	6.20	4.80	3.72	2.40	1.86	49.7
7	0.62	1.40	2.48	3.90	5.27	6.30	7.44	6.51	4.80	2.79	1.20	0.62	43.4
8	1.24	1.68	3.41	4.80	6.20	6.90	7.44	6.51	5.10	3.41	1.80	0.93	49.4
9	2.17	2.80	4.03	5.10	5.89	6.60	7.44	6.82	5.70	4.03	2.70	1.86	55.1
10	0.93	1.68	3.10	4.50	5.89	7.20	8.06	7.13	5.10	3.10	1.50	0.93	49.1
11	1.55	2.24	3.10	4.50	5.89	7.20	8.06	7.44	5.70	3.72	2.10	1.55	53.0
12	1.24	1.96	3.41	5.10	6.82	7.80	8.06	7.13	5.40	3.72	1.80	0.93	53.3
13	1.24	1.96	3.10	4.80	6.51	7.80	8.99	7.75	5.70	3.72	1.80	0.93	54.3
14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0
15	1.24	2.24	3.72	5.70	7.44	8.10	8.68	7.75	5.70	4.03	2.10	1.24	57.9
16	1.55	2.52	4.03	5.70	7.75	8.70	9.30	8.37	6.30	4.34	2.40	1.55	62.5
17	1.86	2.80	4.65	6.00	8.06	9.00	9.92	8.68	6.60	4.34	2.70	1.86	66.5
18	2.48	3.36	5.27	6.90	8.68	9.60	9.61	8.68	6.90	4.96	3.00	2.17	71.6

Figure A1. California Department of Water Resources ETo Zone Map

Table A3. 1999-2003 Average evapotranspiration of irrigation water adjusted for bare spots and decreased vigor (ETirr-Adjusted) values by crop group for ETo Zones 12 and 15

	Zone 12 Average ETirr
Crop Group	AF/Acre
ALFALFA	3.45
CITRUS	2.48
CORN	1.92
COTTON	2.21
FIELD CROPS	1.66
FRUITS	2.59
GRAPES	2.06
NURSERY	2.71
NUTS	3.02
SMALL GRAINS	0.91
VEGETABLES	1.55

	Zone 15 Average ETirr
Crop Group	AF/Acre
ALFALFA	3.92
CITRUS	2.98
CORN	2.13
COTTON	2.47
FIELD CROPS	1.86
FRUITS	2.83
GRAPES	2.28
NURSERY	3.00
NUTS	3.21
SMALL GRAINS	1.14
VEGETABLES	1.79

Table A4 shows which district is in each ETo Zone.

Table A4. Districts in each ETo Zone.

ETo Zone	District
15	Arvin Edison Water Storage District
15	Delano-Earlimart Irrigation District
15	Shafter-Wasco Irrigation District
15	Southern San Joaquin Municipal Utility District
12	Saucelito Irrigation District
12	Tea Pot Dome Water District
12	Terra Bella Irrigation District
12	Lower Tule River Irrigation District
12	Porterville Irrigation District
12	Tulare Irrigation District
12	Exeter Irrigation District
12	Ivanhoe Irrigation District
12	Lindmore Irrigation District
12	Lindsay-Strathmore Irrigation District
12	Lewis Creek Water District
12	Orange Cove Irrigation District
12	Stone Corral Irrigation District
12	Fresno Irrigation District
12	Garfield Irrigation District
12	International Irrigation District
12	Chowchilla Water District
12	Madera Irrigation District
12	Gravelly Ford Water District

Irrigation District Supply

Irrigation districts in the Friant service area are supplied by Millerton Lake through Friant Dam either by the Friant-Kern Canal or the Madera Canal. Some districts in the Friant service area also receive water from "local" supplies that include Kings, Kaweah, Tule, Kern, Fresno, and Chowchilla Rivers. These supplies are shown in **Table A5** on an average annual basis from 1999 to 2003. This data was obtained from the districts' water management plans and through personal communications with the districts.

Table A5. 1999-2003 average annual deliveries from the Friant-Kern Canal, Madera Canal, and local surface supplies.

	1999-2003 Average		
	F-K and Madera Canals	Local Sources	Total
District	AF	AF	AF
Arvin Edison Water Storage District	69,630	47,635	117,265
Delano-Earlimart Irrigation District	121,731	5,935	127,666
Shafter-Wasco Irrigation District	58,376	0	58,376
Southern San Joaquin Municipal Utility District	110,636	0	110,636
Saucelito Irrigation District	29,992	3,452	33,444
Tea Pot Dome Water District	6,829	0	6,829
Terra Bella Irrigation District	17,884	0	17,884
Lower Tule River Irrigation District	127,940	38,023	165,964
Porterville Irrigation District	14,043	10,912	24,955
Tulare Irrigation District	76,674	67,935	144,609
Exeter Irrigation District	13,955	0	13,955
Ivanhoe Irrigation District	9,812	3,659	13,471
Lindmore Irrigation District	37,795	0	37,795
Lindsay-Strathmore Irrigation District	19,968	2,154	22,122
Lewis Creek Water District	721	0	721
Orange Cove Irrigation District	29,287	0	29,287
Stone Corral Irrigation District	7,581	0	7,581
Fresno Irrigation District	14,645	409,528	424,173
Garfield Irrigation District	3,672	0	3,672
International Irrigation District	1,404	0	1,404
Chowchilla Water District	95,434	42,802	138,236
Madera Irrigation District	119,671	48,674	168,345
Gravelly Ford Water District	5,739	0	5,739
Total	**993,421**	**680,707**	**1,674,128**

In cases of significant drought, Class 1 water may be reduced if that water is not available.

The final computations for net groundwater extraction are shown in **Table A6**.

Table A6. Data by district including estimated net groundwater extraction

	Column A – from Table A1	Column B – from Tables A1-A3	Column C – from Table A5	Column B minus Column C
District	Total Irrigated Acreage	1999-2003 Evapotranspiration of Irrigation Water Adjusted	1999-2003 Total Average Surface Deliveries[1, 2]	1999-2003 Average Net Groundwater Extraction
	Acres	AF	AF	AF
ARVIN-EDISON W.S.D.	110,754	225,906	117,265	108,641
DELANO-EARLIMART I.D.	47,892	111,826	127,666	-15,840
SHAFTER-WASCO I.D.	30,531	81,081	58,376	22,705
SOUTHERN SAN JOAQUIN MUD	43,589	115,823	110,636	5,186
SAUCELITO I.D.	17,001	34,509	33,444	1,065
TEA POT DOME W.D.	2,947	6,727	6,829	-102
TERRA BELLA I.D.	9,976	23,908	17,884	6,024
LOWER TULE RIVER I.D.	87,865	180,381	165,964	14,417
PORTERVILLE I.D.	12,848	29,709	24,955	4,754
TULARE I.D.	60,702	123,341	144,609	-21,268
EXETER I.D.	11,947	27,278	13,955	13,323
IVANHOE I.D.	10,269	23,549	13,471	10,077
LINDMORE I.D.	23,984	55,159	37,795	17,364
LINDSAY-STRATHMORE I.D.	11,998	27,482	22,122	5,360
LEWIS CREEK W.D.	737	1,629	721	909
ORANGE COVE I.D.	24,837	56,371	29,287	27,084
STONE CORRAL I.D.	6,049	13,257	7,581	5,676
FRESNO I.D.	139,763	303,056	424,173	-121,117
GARFIELD W.D.	1,000	2,320	3,672	-1,352
INTERNATIONAL W.D.	655	1,500	1,404	96
CHOWCHILLA W.D.	65,724	146,224	138,236	7,988
MADERA I.D.	102,660	218,942	168,345	50,597
GRAVELLY FORD W.D.	7,503	16,776	5,739	11,038
Total	**831,229**	**1,826,753**	**1,674,128**	**152,624**

[1]In addition, the City of Fresno receives approximately 60,000 AF/Year.

[2]Some floodwater used for groundwater recharge is included in the Average Surface Deliveries category.

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Appendix B – Topic 2

Estimated Irrigation Water Well Pumping (Gross)

Appendix B – Topic 2

Estimated Irrigation Water Well Pumping (Gross)

Where conjunctive use is possible in the Friant service area, on-farm well pumping is an established practice to supplement surface deliveries – especially in dry years. On-farm well pumping is increasingly being used as the sole final source of on-farm water for drip/micro systems, which may require cleaner water and a more flexible source than can be provided by the irrigation district surface deliveries. The groundwater supply is ultimately recharged by surface water deliveries to the districts in the form of over-irrigation on some fields, through deliberate recharge in groundwater recharge basins, or through canal seepage.

There is no good database available that updates well pumping volumes on an annual basis, or by district. Irrigation district estimates of farm groundwater pumping are poor, for the following reasons:

1. Irrigation districts are not required to even know where the wells are on private property.
2. Irrigation districts do not have the resources to have their employees search for private wells and obtain pumped volume numbers.
3. Many, if not most, of the private wells do not have flow meters with totalizers.

The Public Utilities Commission's estimates of agricultural pumping are also poor, as evidenced by recent (Spring 2005) attempts within the California Energy Commission to analyze those records. Local utilities such as Southern California Edison and Pacific Gas and Electric Company do not release their energy billing records – and even if they did, an estimate of pumping volume would require further estimates of pumping plant efficiency, discharge pressure, drawdown, and depth of standing water.

In 2003, ITRC was contracted by the California Energy Commission to estimate the electrical energy consumed by agricultural irrigation pumping throughout the state of California. (Burt et al, 2003). At this time, those estimates have been accepted within the CEC as the best available.

This study's estimate of Friant service area gross irrigation well pumping utilized many of the same procedures used in the CEC study (Burt et al, 2003).

Basic Computations

The formula for gross ground water pumping is:

$$\text{Pumping} = [\text{ETirrp} - (\text{IDSW}) \times \text{CEF} \times \text{AE}/100] \times 100/\text{AE}$$

Where

Pumping = Gross irrigation well (ground) water pumping

ETirrp = The ET of irrigation water, not de-rated for bare spots and poor vigor in a field. That is, it is the ETirr value that is used for irrigation scheduling as opposed to the ETirr value used in water balance computations.

IDSW = Surface water available to each irrigation district. Defined in Topic 1. Shown for 1987-2003 in **Table B3.**

CEF = Conveyance efficiency of the irrigation districts, divided by 100. This value has been estimated by each irrigation district.

Table B1. Conveyance efficiency, by district*

District	District Conveyance Efficiency/100
Arvin Edison Water Storage District	0.95
Chowchilla Water District	0.70
Delano-Earlimart Irrigation District	0.99
Exeter Irrigation District	0.99
Fresno Irrigation District	0.81
Garfield Water District	0.99
Gravelly Ford WD	0.60
International Water District	0.99
Ivanhoe Irrigation District	0.99
Lewis Creek	0.99
Lindmore Irrigation District	0.99
Lindsay-Strathmore Irrigation District	0.95
Lower Tule River Irrigation District	0.65
Madera Irrigation District	0.70
Orange Cove Irrigation District	0.99
Porterville Irrigation District	0.65
Saucelito Irrigation District	0.99
Shafter-Wasco Irrigation District	0.99
Southern San Joaquin MUD	0.98
Stone Corral	0.99
Tea Pot Dome Water District	0.99
Terra Bella Irrigation District	0.99
Tulare Irrigation District	0.65

* Districts with low conveyance efficiencies have unlined canals for deliberate seepage for recharge of groundwater.

AE = Application Efficiency of on-farm irrigation.

ITRC has teams of students that measure Distribution Uniformity (DU) values for the Friant service area most summers. However, DU only defines the uniformity of water distribution, which is not the same as Application Efficiency. Burt et al (1997) define these values as follows:

$$DU_{lq} = \frac{\text{avg. low quarter depth}}{\text{average depth of water accumulated in all elements}}$$

$$AE = \frac{\text{avg. depth of irrig. water contributing to target}}{\text{avg. depth of irrig. water applied}} \times 100\%$$

The actual AE values will depend upon the irrigation event, farmer, irrigation method, field, etc. The values in the table below are best estimates based on years of field experience in this and other areas, and theoretical analysis. In general, drip/micro AE values are highest because there is often some under-irrigation with these irrigation methods. Sprinkler AE values depend upon the type of sprinkler system. In the Friant service area, the predominant sprinkler method is hand move sprinkler. When compared against local surface irrigation practices, the actual AE values are probably similar.

In many areas, surface irrigation methods (furrow and border strip) have the lowest on-farm application efficiencies. However, in the Friant service area, both the low infiltration rates and the tendency of irrigators to stop irrigation early to prevent/minimize surface runoff contribute to some under-irrigation. Under-irrigation results in relatively high AE values because there are minimum losses due to deep percolation and uncollected runoff. If there was no under-irrigation in parts of the fields, the AE would be lower, because there would be more deep percolation.

Of course, there will be exceptions found with every irrigation method and between fields. Detailed work by ITRC to examine AE values in other areas of the state has shown a very wide range of individual values, regardless of irrigation method. Again, the AE values used in this report are higher than are normally reported in publications, because of local scheduling and distribution uniformity problems that create temporary or localized under-irrigation within fields. The new effect, for this report, is that these high AE values may underestimate the gross groundwater pumping estimates. Therefore the estimates in Table 3 are conservative.

Table B2. AE estimates used in ITRC computations

Application Efficiency, %		
Surface	Sprinkler	Drip/Micro
75	75	85

Table B3 shows the annual surface water deliveries to districts in the Friant WUA from 1987 to 2003. These include deliveries from the Friant-Kern and Madera Canals as well as from local surface water supply sources. **Table B4** shows the average annual surface deliveries for selected periods of record.

Table B3. 1987-2003 - Annual surface water deliveries (Acre-Feet) in the Friant service area from the Friant-Kern Canal and other local supplies.

District	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Arvin Edison WSD	123,808	111,250	113,614	57,839	36,622	56,573	137,930	76,771	166,780	174,272	184,812	130,834	164,163	155,257	44,313	94,556	128,035
Delano-Earlimart Irrigation District	110,583	105,118	105,446	81,174	110,044	90,414	140,611	87,670	129,338	145,404	154,958	110,812	137,890	135,838	115,583	127,676	121,342
Shafter-Wasco ID	48,767	42,476	51,475	31,316	45,705	44,197	81,448	37,245	72,246	71,932	69,295	35,387	60,890	61,510	56,403	50,925	62,151
Southern San Joaquin MUD	96,779	88,648	96,293	68,765	85,052	83,422	114,826	109,357	116,868	124,230	123,457	91,742	113,646	125,139	100,252	102,202	111,942
Saucelito ID	28,638	22,325	25,837	20,841	24,772	22,586	3,736	23,982	44,577	49,975	40,937	49,439	37,534	42,646	28,270	27,370	31,400
Tea Pot Dome WD	7,195	5,769	7,350	6,220	6,401	7,324	6,526	6,974	7,500	6,701	7,194	6,153	8,390	6,906	6,526	6,313	6,011
Terra Bella ID	21,703	22,152	23,372	22,807	18,267	20,765	19,200	20,737	18,108	19,846	20,677	20,677	13,864	17,534	18,618	20,530	18,875
Lower Tule River ID	100,360	86,809	151,773	47,920	94,882	62,076	345,400	118,960	369,200	269,424	277,992	343,452	184,012	237,717	106,456	113,634	188,000
Porterville ID	22,306	20,876	18,289	11,723	12,603	16,598	18,497	25,808	23,224	26,674	28,584	25,617	21,510	26,463	26,080	26,820	23,903
Tulare Irrigation District	20,733	60,548	56,848	337	78,611	32,628	406,674	85,295	296,914	272,621	239,681	310,773	149,432	216,242	78,415	103,614	175,342
Exeter Irrigation District	9,787	9,122	11,712	7,893	11,127	10,246	16,640	8,771	17,755	18,547	17,200	14,121	14,866	15,723	13,784	12,744	12,657
Ivanhoe Irrigation District	11,280	9,945	11,976	7,400	11,959	8,700	19,674	9,016	18,576	16,010	15,184	13,987	13,846	14,095	12,731	11,470	15,214
Lindmore ID	31,055	33,217	35,034	21,585	35,590	34,259	42,578	25,980	41,471	47,003	41,841	37,637	38,408	35,999	37,815	34,416	42,335
Lindsay-Strathmore ID	26,755	26,589	29,668	30,016	23,146	27,276	21,635	21,685	22,915	21,423	27,061	19,241	23,785	21,770	23,510	23,242	18,304
Lewis Creek WD	1,309	1,142	1,298	1,144	1,258	1,396	1,450	1,160	1,586	1,314	2,274	538	1,408	174	0	1,142	879
Orange Cove ID	30,619	30,614	32,773	28,061	33,607	34,793	35,488	23,620	28,456	26,938	29,902	30,091	28,687	26,961	30,312	30,310	30,166
Stone Corral ID	6,974	8,694	10,001	8,888	8,861	9,147	8,577	7,465	8,161	8,974	9,652	5,394	5,946	7,274	7,643	8,597	8,447
Fresno Irrigation District	369,420	387,925	368,907	286,386	350,784	341,357	570,604	397,194	309,310	506,460	554,052	417,252	494,631	482,557	288,656	403,509	451,511
Garfield Irrigation District	3,761	2,369	3,427	3,662	2,382	4,178	4,077	3,168	1,685	4,319	3,306	1,117	5,484	3,228	3,180	3,439	3,029
International ID	930	1,035	1,240	1,146	1,172	851	1,416	1,442	1,320	2,077	1,419	1,553	1,238	1,366	1,465	1,532	1,419
Chowchilla Water District	120,793	64,429	47,326	40,482	73,288	55,775	213,552	109,421	157,471	178,073	179,520	133,706	174,096	173,559	140,519	90,946	112,060
Madera Irrigation District	105,248	92,162	111,451	80,769	122,751	101,162	332,416	124,259	264,346	276,186	238,937	208,322	187,794	195,926	147,014	144,113	166,877
Gravelly Ford WD	0	0	0	0	0	0	17,028	0	19,691	15,431	11,623	6,634	3,429	5,207	2,555	8,817	8,686
Total	1,298,803	1,233,214	1,315,110	866,374	1,188,884	1,065,723	2,559,983	1,325,980	2,137,498	2,283,834	2,279,558	2,014,479	1,884,949	2,009,091	1,290,100	1,447,917	1,738,585

Table B4. Average annual surface deliveries in the Friant service area for specific periods of record (Acre-Feet per Year)

District	1987-1992	1993-1998	1999-2003
Arvin Edison Water Storage District	83,284	145,233	117,265
Delano-Earlimart Irrigation District	100,463	128,132	127,666
Shafter-Wasco Irrigation District	43,989	61,259	58,376
Southern San Joaquin Municipal Utility District	86,493	113,413	110,636
Saucelito Irrigation District	24,167	35,441	33,444
Tea Pot Dome Water District	6,710	6,841	6,829
Terra Bella Irrigation District	21,511	19,874	17,884
Lower Tule River Irrigation District	90,637	287,405	165,964
Porterville Irrigation District	17,066	24,734	24,955
Tulare Irrigation District	41,618	268,660	144,609
Exeter Irrigation District	9,981	15,506	13,955
Ivanhoe Irrigation District	10,210	15,408	13,471
Lindmore Irrigation District	31,790	39,418	37,795
Lindsay-Strathmore Irrigation District	27,242	22,327	22,122
Lewis Creek Water District	1,258	1,387	721
Orange Cove Irrigation District	31,745	29,083	29,287
Stone Corral Irrigation District	8,761	8,037	7,581
Fresno Irrigation District	350,797	459,145	424,173
Garfield Irrigation District	3,297	2,945	3,672
International Irrigation District	1,062	1,538	1,404
Chowchilla Water District	67,016	161,957	138,236
Madera Irrigation District	102,257	240,744	168,345
Gravelly Ford Water District	0	11,735	5,739
Total	**1,161,351**	**2,100,222**	**1,674,128**

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Appendix C – Topic 3

Estimated Irrigation Water Well Pumping Energy Requirements by Year 2025 Under the Spring Run Release Scenario

Appendix C

Estimated Irrigation Water Well Pumping Energy Requirements by Year 2025 Under the Spring Run Release Scenario

Reductions in surface irrigation water deliveries associated with increased releases to the San Joaquin River will create increased demand for groundwater pumping. The average gross irrigation water pumping from years 1999-2003 was used for this analysis. These years of detailed study were selected because they represent recent conditions.

1. Present Volume of Groundwater Pumping

The ITRC assumes the average gross volume of groundwater pumping in Table C1 will be the same by 2025 with **NO CHANGE** in deliveries to Friant districts. This assumes no change in irrigated acreage, crop mix, or crop evapotranspiration demands. Undoubtedly, there would be a change in crop mix due to normal market forces – even without a change in water availability from the Friant system. But it is beyond the scope of this analysis to speculate on those changes.

The overall goal of this analysis is to estimate the increase in energy use after 20 years of surface water reductions to the Friant districts. Therefore, the gross groundwater pumping by 2025 will be used for the increased energy use estimates.

Table C1. 1999-2003 average volume of gross irrigation well pumping in each district assuming no change in Friant water availability

District	Gross Irrigation Well Pumping 1999	2000	2001	2002	2003	1999-2003 Average Gross Irrigation Well Pumping
	AF	AF	AF	AF	AF	AF
ARVIN-EDISON W.S.D.	162,000	162,794	254,962	232,878	183,680	199,263
DELANO-EARLIMART I.D.	23,714	17,331	30,885	31,273	23,402	25,321
SHAFTER-WASCO I.D.	57,464	54,171	54,105	67,177	47,365	56,056
SOUTHERN SAN JOAQUIN MUD	59,767	42,106	50,945	60,650	37,971	50,288
SAUCELITO I.D.	7,376	1,356	23,294	23,983	18,623	14,926
TEA POT DOME W.D.	302	2,239	2,115	2,346	2,907	1,982
TERRA BELLA I.D.	17,921	15,966	12,031	10,083	12,430	13,686
LOWER TULE RIVER I.D.	119,121	85,455	206,957	200,232	138,889	150,131
PORTERVILLE I.D.	26,048	22,187	26,350	25,288	26,443	25,263
TULARE I.D.	72,751	28,562	134,371	117,218	59,693	82,519
EXETER I.D.	20,785	21,541	21,073	22,175	23,279	21,771
IVANHOE I.D.	16,597	18,289	16,824	18,181	15,496	17,077
LINDMORE I.D.	35,203	37,819	37,366	40,332	33,142	36,773
LINDSAY-STRATHMORE I.D.	12,606	15,881	13,326	13,601	19,252	14,933
LEWIS CREEK W.D.	895	1,913	2,301	1,160	1,424	1,539
ORANGE COVE I.D.	44,136	49,093	42,903	42,918	44,902	44,790
STONE CORRAL I.D.	11,462	10,650	9,800	8,896	9,267	10,015
FRESNO I.D.	33,729	41,752	176,467	79,548	34,879	73,275
GARFIELD W.D.	0	0	44	0	158	40
INTERNATIONAL W.D.	670	690	431	371	550	542
CHOWCHILLA W.D.	76,308	77,632	116,579	149,399	127,277	109,439
MADERA I.D.	155,105	145,597	212,958	211,445	191,482	183,317
GRAVELLY FORD W.D.	20,814	19,847	22,199	18,105	17,749	19,743
Total	**974,775**	**872,871**	**1,468,285**	**1,377,259**	**1,070,259**	**1,152,690**

2. Estimated increase in groundwater extraction per year under Spring Run release scenario

Table C2 shows the increase in annual groundwater extraction due directly to reduction in surface deliveries (from Dan Steiner's model). The actual average annual volume of surface water reduction for irrigation districts under the Spring Run release scenario is 347,659 AF.

Table 2. Increase in average annual groundwater extraction from Dan Steiner's preliminary surface water reductions to each district summarized by Economic Zones.

District	Steiner Est. Increase in Groundwater Extraction AF/Year
ARVIN-EDISON W.S.D.	53,469
DELANO-EARLIMART I.D.	31,924
SHAFTER-WASCO I.D.	15,458
SOUTHERN SAN JOAQUIN MUD	26,051
SAUCELITO I.D.	8,904
TEA POT DOME W.D.	1,447
TERRA BELLA I.D.	5,594
LOWER TULE RIVER I.D.	46,743
PORTERVILLE I.D.	7,490
TULARE I.D.	26,485
EXETER I.D.	5,008
IVANHOE I.D.	2,645
LINDMORE I.D.	9,595
LINDSAY-STRATHMORE I.D.	5,305
LEWIS CREEK W.D.	280
ORANGE COVE I.D.	7,562
STONE CORRAL I.D.	1,929
FRESNO I.D.	11,010
GARFIELD W.D.	675
INTERNATIONAL W.D.	231
CHOWCHILLA W.D.	34,097
MADERA I.D.	43,701
GRAVELLY FORD W.D.	2,055
Total	**347,659**

3. Present irrigation well pumping energy requirements per unit volume of water pumped

Table C3 shows the current estimated pumping depth, estimated pump total dynamic head, pump efficiency, and pumping energy requirement.

Ken Schmidt provided pumping depth data from his analysis of the DWR Spring 2003 groundwater elevations. The ITRC checked these values independently and agrees with the values in Table C3.

The total dynamic head (TDH) is the pumping depth plus estimates for discharge pressure and column loss (drawdown is included in the pumping depth estimates). For this analysis, 11 feet, was added to the pumping depth to account for discharge pressure and column loss.

The current average on-farm pump efficiency in each district is shown in Table C3. The ITRC has a database with over 5000 pump tests from throughout the State conducted from 2000-2004. Originally pump efficiency data was summarized by county. It was then summarized/estimated by ITRC for each District.

Gross irrigation well pumping energy requirements are calculated as:

$$\textbf{KWh/AF} = \mathbf{1.023 \times TDH/(PP_{EFF}/100)}$$

Table C3. Current energy requirements for irrigation water well pumping in Friant service ara.

	Current			
District	Initial Pump Depth (Schmidt)	Total Dynamic Head	Pumping Plant Efficiency	Groundwater Pumping Energy Requirement
	ft	%	%	kWh/AF
ARVIN-EDISON W.S.D.	410	421	53.2	810
DELANO-EARLIMART I.D.	180	191	53.2	367
SHAFTER-WASCO I.D.	325	336	53.2	646
SOUTHERN SAN JOAQUIN MUD	175	186	53.2	358
SAUCELITO I.D.	175	186	52.3	364
TEA POT DOME W.D.	155	166	52.3	325
TERRA BELLA I.D.	140	151	52.3	295
LOWER TULE RIVER I.D.	165	176	52.3	344
PORTERVILLE I.D.	60	71	52.3	139
TULARE I.D.	150	161	52.3	315
EXETER I.D.	75	86	52.3	168
IVANHOE I.D.	85	96	52.3	188
LINDMORE I.D.	70	81	52.3	158
LINDSAY-STRATHMORE I.D.	60	71	52.3	139
LEWIS CREEK W.D.	55	66	52.3	129
ORANGE COVE I.D.	40	51	52.3	100
STONE CORRAL I.D.	45	56	52.3	110
FRESNO I.D.	85	96	54.5	180
GARFIELD W.D.	160	171	54.5	321
INTERNATIONAL W.D.	55	66	54.5	124
CHOWCHILLA W.D.	150	161	54.5	302
MADERA I.D.	150	161	54.5	302
GRAVELLY FORD W.D.	140	151	54.5	283

4. Future irrigation well pumping energy requirements per unit volume of water pumped

The increase in groundwater pumping will cause a drop in groundwater levels. This impacts the energy requirement in two ways; (i) the water must be pumped from a greater depth (increased TDH) and (ii) a decrease in pumping plant efficiency (PPEFF).

TDH is calculated as the existing pumping depth plus the change in pumping depth under the Spring Run release scenario and includes column losses and discharge pressure (drawdown is included in pumping depth). As the TDH increases and PPEFF decreases the kWh/AF increases meaning it requires more energy to pump one acre-foot (AF) of water.

Not only do we have more water that needs to be pumped, as the groundwater level drops, more energy is required to pump that additional water. In addition, it requires additional energy to pump the existing groundwater demands.

Table C4 shows the increased energy requirement per volume of irrigation water pumped by district by year 2025 under the Spring Run release scenario. The increase in pumping depth shown in the table was estimated by Ken Schmidt. Heading descriptions and calculation explanations are outlined in the previous section.

Table C4. Estimated future irrigation well pumping energy requirements by 2025 under the Spring Run release scenario

	Current	Under Spring Run release scenario by Year 2025			
District	Initial Pump Depth (Schmidt)	Change in Pump Depth (Schmidt)*	Total Dynamic Head	Pumping Plant Efficiency	Groundwater Pumping Energy Requirement
	ft	ft	ft	%	kWh/AF
ARVIN-EDISON W.S.D.	410	290	711	45.0	1,616
DELANO-EARLIMART I.D.	180	166	357	45.0	812
SHAFTER-WASCO I.D.	325	176	512	45.0	1,164
SOUTHERN SAN JOAQUIN MUD	175	70	256	45.0	582
SAUCELITO I.D.	175	150	336	45.0	764
TEA POT DOME W.D.	155	150	316	45.0	718
TERRA BELLA I.D.	140	150	301	45.0	684
LOWER TULE RIVER I.D.	165	158	334	45.0	759
PORTERVILLE I.D.	60	150	221	45.0	502
TULARE I.D.	150	174	335	45.0	762
EXETER I.D.	75	94	180	45.0	409
IVANHOE I.D.	85	60	156	45.0	355
LINDMORE I.D.	70	148	229	45.0	521
LINDSAY-STRATHMORE I.D.	60	40	111	45.0	252
LEWIS CREEK W.D.	55	40	106	45.0	241
ORANGE COVE I.D.	40	100	151	45.0	343
STONE CORRAL I.D.	45	100	156	45.0	355
FRESNO I.D.	85	0	96	54.5	180
GARFIELD W.D.	160	0	171	54.5	321
INTERNATIONAL W.D.	55	0	66	54.5	124
CHOWCHILLA W.D.	150	176	337	45.0	766
MADERA I.D.	150	102	263	45.0	598
GRAVELLY FORD W.D.	140	102	253	45.0	575

*The change in pump depth values indicates a decrease in groundwater level or an increase in pump depth. Some confusion is often associated with the positive or negative sign that is shown with these numbers. These values could be shown as either a negative (indicating a decrease in groundwater level) or a positive (indicating an increase in pumping depth); the result is the same – an increase in total dynamic head.

Appendix D
Information Used for Analysis, List of Recent Publications, List of Cases

Appendix D

Information Used for Analysis, List of Recent Publications, List of Cases

Information and Data Used for Analysis

Transmitted on attached Compact Disk:

1. ITRC-FAO 56 Evapotranspiration Model and Input Data
    - Folder - FKET
2. District Crop Acreage
    - Friant District Acreage to ITRC 1980-2004.xls
3. District Surface Water Deliveries
    - FWUA District Inflow Final.xls
4. Gross Groundwater Pumping and 2025 Pumping Energy Requirements
    - FWUA Crop Acreage and ET 87-04 Final.xls
    - ITRC FWUA Pumping 87-03 Final.xls
5. Net Groundwater Extraction
    - FWUA Crop Acreage and ETadjusted 87-04 Final.xls
    - ITRC FWUA Net Extraction 87-03 Final.xls

List of Court Cases – Deposition or at Trial in the last 4 years

Within the last 4 years, I have not appeared in court but I did testify before the Water Resources Control Board earlier this year on behalf of the Exchange Contractors of the San Joaquin River.

I am currently retained as an expert on:
- A case involving leaking irrigation fittings in Washington. This case is in its preliminary stages. Client: A manufacturer who is the defendant.

- A case involving problems with a large drip system in central California. This case has involved depositions and settlement discussions and is not yet finalized. Client: A farmer who is the plaintiff.

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Statement of Hourly Rate

Fees are as follows:

$160/hr, plus all expenses for regular work.

$ 240/hr, plus all expenses for testimony and depositions. 4 hours minimum/day while on call for testimony and depostions.

Hourly charges are applied to portal-portal time – which includes travel, waiting to testify, etc.
Payments are to be made to "Cal Poly Foundation" and mailed to me at ITRC.