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Technical Memorandum

To: RMC Water and Environment
From: Davids Engineering
Date: May 7, 2014
Subject: **Sacramento Central Groundwater Authority 2011-2012 Agricultural Demand and Groundwater Pumping Estimates**

Overview

This technical memorandum describes an analysis of agricultural water demands for irrigation and corresponding groundwater use for 2011 and 2012 within the boundaries of the Sacramento Central Groundwater Authority (SCGA), hereinafter referred to as the Study Area. The analysis was performed for field polygons potentially under agricultural production based on land use information compiled by the Sacramento Area Council of Governments (SACOG, Bell 2013). The Study Area and field polygons are shown in Figure 1. The Study Area is generally bounded by the American River on the north, Interstate 5 on the west, New Hope Road and Dillard Road on the south, and Prairie City and Scott Road on the east. Land uses and types outside of the Sacramento urban area include native and riparian vegetation, agriculture, and rural residential development. Agriculture is most dense along the Cosumnes River and is almost wholly dependent on groundwater for irrigation.

The analysis of irrigation demands was performed for agricultural and rural residential lands in the area. Existing land use data developed by SACOG for 2008 were updated to reflect 2011 and 2012 cropping based on information from the Cropland Data Layer (CDL) developed by the National Agricultural Statistics Service (NASS)[1]. Then, evapotranspiration (ET) was estimated using a crop coefficient-reference evapotranspiration calculation approach as described by Allen et al. (1998). Crop coefficients were developed based on available Surface Energy Balance Algorithm for Land (SEBAL, Bastiaanssen et al., 2005) data describing actual ET for the 2009 growing season covering the study area.

Following the estimation of total actual ET, the Integrated Water Flow Model (IWFM) Demand Calculator (IDC) version 4.0.286 (DWR 2013) was configured and applied to perform daily root-zone-water-balance calculations for 2011 and 2012 and to estimate of the amount of ET derived from applied irrigation water (ET_{aw}) and from precipitation (ET_{pr}) for individual crop-soil groups. IDC was then configured and run to estimate applied water (irrigation) demands.

[1] Available at http://nassgeodata.gmu.edu/CropScape/. Accessed 2/24/2014.

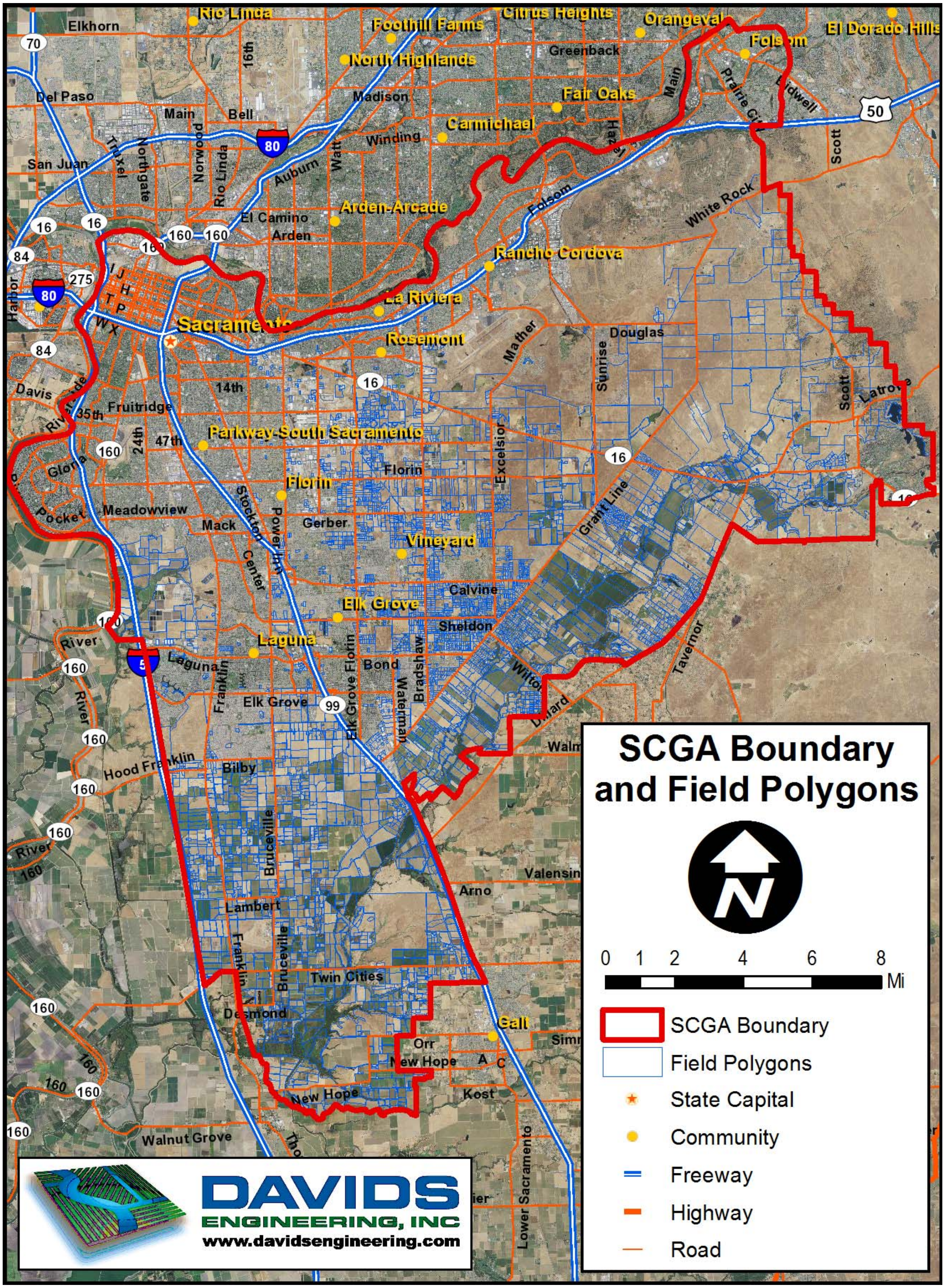


Figure 1. Field Polygons and SCGA Boundary.

Development of 2011 and 2012 Agricultural Land Use

This section describes the development of agricultural land use estimates for SCGA for 2011 and 2012.

Development of Land Use Classes

General land use classes with similar ET demands and irrigation practices were developed for the Study Area to provide consistency between the land use classes in SACOG 2008 and those in the CDL. Four agricultural land use classes were developed for agricultural land (Fallow, Field and Truck, Pasture and Hay, and Vineyards and Orchards), two for native vegetation (Native and Riparian/Wetlands), and one for rural residential. These classes are summarized in Table 1, along with corresponding land use classes in 2008, the number of field polygons, and the acreage for each class.

Table 1. Land Use Classes for Ag Water Demand Update for SCGA, 2011-2012.

SCGA Land Use	SACOG Land Uses	Number of Polygons	Acres
Fallow	Fallow, Other, Other Agriculture	146	3,728
Field and Truck	Beans, dry; Corn; Field Crops; Large Scale Local Vegetables; Rice; Safflower; Tomatoes, processing	311	10,309
Pasture and Hay	Alfalfa; Grass Hay; Hay, all; Pasture; Pasture/Natural Vegetation; Sudan Grass; Wheat	1,220	24,406
Vineyards and Orchards	Citrus, Grapes, Grapes/Vineyards, Fruits & Nuts unspecified, Nursery, Other, Walnuts	209	8,292
Native	Fallow; Natural Vegetation; Natural Vegetation/Wetlands; Other; Other Agriculture; Pasture/Natural Vegetation; Rural Residential/Developed	637	46,882
Riparian/ Wetlands	Natural Vegetation; Natural Vegetation/Wetlands; Pasture/Natural Vegetation	304	8,444
Rural Residential	Natural Vegetation/Wetlands; Other; Pasture/Natural Vegetation; Rural Residential/Developed	2,238	11,943

The land use from the 2008 SACOG data was reclassified and updated based on more recent land use data and based on visual inspection of available aerial and satellite imagery. As a result, some of the SACOG 2008 land use classes are listed more than once corresponding to different SCGA Land Uses. For example, the SACOG land use "Natural Vegetation" (Column 2 in Table 1) is listed under the "Native", as well as "Native and Riparian/Wetlands SCGA" land use classes (Column 1 in Table 1). The reason is that fine-scale riparian mapping data (CDFW 2013) is available to differentiate "Native" and "Riparian/Wetlands", both previously designated as "Natural Vegetation". The process is described in the following section.

Similarly, the CDL data were assigned (or reclassified) to the seven SCGA land use types developed in the SACOG 2008 land use reclassifying process. The cross-references developed to reclassify the CDL data are provided in Table 2. Although many of the CDL land uses were not found in the SCGA area, all CDL land use classes were assigned to a general SCGA land use type to facilitate future updates.

Table 2. SCGA Land Use Classes and Corresponding CDL Land Use Classes.

SCGA Land Use	CDL Code	CDL Land Use
Fallow	61	Fallow/Idle Cropland
Field and Truck	1	Corn
Field and Truck	2	Cotton
Field and Truck	3	Rice
Field and Truck	4	Sorghum
Field and Truck	5	Soybeans
Field and Truck	6	Sunflower
Field and Truck	10	Peanuts
Field and Truck	11	Tobacco
Field and Truck	12	Sweet Corn
Field and Truck	13	Popcorn or Ornamental Corn
Field and Truck	14	Mint
Field and Truck	23	Spring Wheat
Field and Truck	26	Dbl Crop WinWht/Soybeans
Field and Truck	31	Canola
Field and Truck	33	Safflower
Field and Truck	34	Rape Seed
Field and Truck	35	Mustard
Field and Truck	41	Sugarbeets
Field and Truck	42	Dry Beans
Field and Truck	43	Potatoes
Field and Truck	45	Sugarcane
Field and Truck	46	Sweet Potatoes
Field and Truck	47	Misc Vegs & Fruits
Field and Truck	48	Watermelons
Field and Truck	49	Onions
Field and Truck	50	Cucumbers
Field and Truck	51	Chick Peas
Field and Truck	52	Lentils
Field and Truck	53	Peas
Field and Truck	54	Tomatoes
Field and Truck	56	Hops
Field and Truck	57	Herbs
Field and Truck	206	Carrots
Field and Truck	207	Asparagus
Field and Truck	208	Garlic
Field and Truck	209	Cantaloupes
Field and Truck	213	Honeydew Melons
Field and Truck	214	Broccoli
Field and Truck	216	Peppers
Field and Truck	219	Greens
Field and Truck	221	Strawberries
Field and Truck	222	Squash
Field and Truck	225	Dbl Crop WinWht/Corn

SCGA Land Use	CDL Code	CDL Land Use
Field and Truck	226	Dbl Crop Oats/Corn
Field and Truck	227	Lettuce
Field and Truck	229	Pumpkins
Field and Truck	230	Dbl Crop Lettuce/Durum Wht
Field and Truck	231	Dbl Crop Lettuce/Cantaloupe
Field and Truck	232	Dbl Crop Lettuce/Cotton
Field and Truck	233	Dbl Crop Lettuce/Barley
Field and Truck	234	Dbl Crop Durum Wht/Sorghum
Field and Truck	235	Dbl Crop Barley/Sorghum
Field and Truck	236	Dbl Crop WinWht/Sorghum
Field and Truck	237	Dbl Crop Barley/Corn
Field and Truck	238	Dbl Crop WinWht/Cotton
Field and Truck	239	Dbl Crop Soybeans/Cotton
Field and Truck	240	Dbl Crop Soybeans/Oats
Field and Truck	241	Dbl Crop Corn/Soybeans
Field and Truck	243	Cabbage
Field and Truck	244	Cauliflower
Field and Truck	245	Celery
Field and Truck	246	Radishes
Field and Truck	247	Turnips
Field and Truck	248	Eggplants
Field and Truck	249	Gourds
Field and Truck	254	Dbl Crop Barley/Soybeans
Native	63	Forest
Native	64	Shrubland
Native	65	Barren
Native	131	Barren
Native	143	Mixed Forest
Native	152	Shrubland
Pasture and Hay	21	Barley
Pasture and Hay	22	Durum Wheat
Pasture and Hay	24	Winter Wheat
Pasture and Hay	25	Other Small Grains
Pasture and Hay	27	Rye
Pasture and Hay	28	Oats
Pasture and Hay	29	Millet
Pasture and Hay	30	Speltz
Pasture and Hay	32	Flaxseed
Pasture and Hay	36	Alfalfa
Pasture and Hay	37	Other Hay/Non Alfalfa
Pasture and Hay	38	Camelina
Pasture and Hay	39	Buckwheat
Pasture and Hay	44	Other Crops
Pasture and Hay	58	Clover/Wildflowers

SCGA Land Use	CDL Code	CDL Land Use
Pasture and Hay	59	Sod/Grass Seed
Pasture and Hay	60	Switchgrass
Pasture and Hay	176	Grassland/Pasture
Pasture and Hay	205	Triticale
Pasture and Hay	224	Vetch
Riparian/Wetlands	87	Wetlands
Riparian/Wetlands	190	Woody Wetlands
Riparian/Wetlands	195	Herbaceous Wetlands
Riparian/Wetlands	83	Water
Riparian/Wetlands	92	Aquaculture
Riparian/Wetlands	111	Open Water
Rural Residential	82	Developed
Rural Residential	121	Developed/Open Space
Rural Residential	122	Developed/Low Intensity
Rural Residential	123	Developed/Med Intensity
Rural Residential	124	Developed/High Intensity
Vineyards and Orchards	55	Caneberries
Vineyards and Orchards	66	Cherries
Vineyards and Orchards	67	Peaches
Vineyards and Orchards	68	Apples
Vineyards and Orchards	69	Grapes
Vineyards and Orchards	70	Christmas Trees
Vineyards and Orchards	71	Other Tree Crops
Vineyards and Orchards	72	Citrus
Vineyards and Orchards	74	Pecans
Vineyards and Orchards	75	Almonds
Vineyards and Orchards	76	Walnuts
Vineyards and Orchards	77	Pears
Vineyards and Orchards	141	Deciduous Forest
Vineyards and Orchards	142	Evergreen Forest
Vineyards and Orchards	204	Pistachios
Vineyards and Orchards	210	Prunes
Vineyards and Orchards	211	Olives
Vineyards and Orchards	212	Oranges
Vineyards and Orchards	217	Pomegranates
Vineyards and Orchards	218	Nectarines
Vineyards and Orchards	220	Plums
Vineyards and Orchards	223	Apricots
Vineyards and Orchards	242	Blueberries
Vineyards and Orchards	250	Cranberries
Unassigned	81	Clouds/No Data
Unassigned	88	Nonag/Undefined
Unassigned	112	Perennial Ice/Snow

Identification of Field Polygons with Fixed Land Use

Field polygons for areas where land use changes are not anticipated were identified as “not in agricultural production” or “fixed land use” based on recent available data from multiple land-use sources. These areas include developed and rural residential areas as well as areas of riparian and native vegetation. Sources of land use data include the following:

- Farmland Mapping and Monitoring Program (FMMP) coverage for Sacramento County for 2010 – identifies agricultural and developed lands. Field polygons comprised of at least 50 percent developed lands based on FMMP were assigned to the Rural Residential land use class.
- SACOG 2008 land use coverage – Polygons identified in 2008 as Rural Residential were assigned to Rural Residential. Polygons identified in 2008 as Vineyards or Orchards were assigned to Vineyards and Orchards.
- Fine-Scale Riparian Vegetation Mapping of the Central Valley Flood Protection Plan Area (CDFW 2013) – identifies native, riparian, agricultural, and urban areas. Field polygons comprised of at least 50 percent riparian or wetland vegetation based on the California Wildlife Habitat Relations (CWHR) classification type were assigned to the Riparian land use class. Field polygons comprised of at least 50 percent native annual grassland based on the California Wildlife Habitat Relations (CWHR) classification type were assigned to the Native land use class.

Polygons assigned fixed land uses were visually inspected and refined based on available imagery for Sacramento County from the National Agricultural Imagery Program (NAIP) for 2009 and 2012. Imagery from 2009 was included because it was acquired only one year after the available 2008 land use dataset and before the 2011 dataset. Figure 2 shows the field polygons with fixed land use for this study. Urban areas are excluded, except to the extent that they may have been urbanized following the development of the 2008 land use coverage. It is recommended that the polygon coverage be reviewed and updated as appropriate for future updates to reflect urbanization.

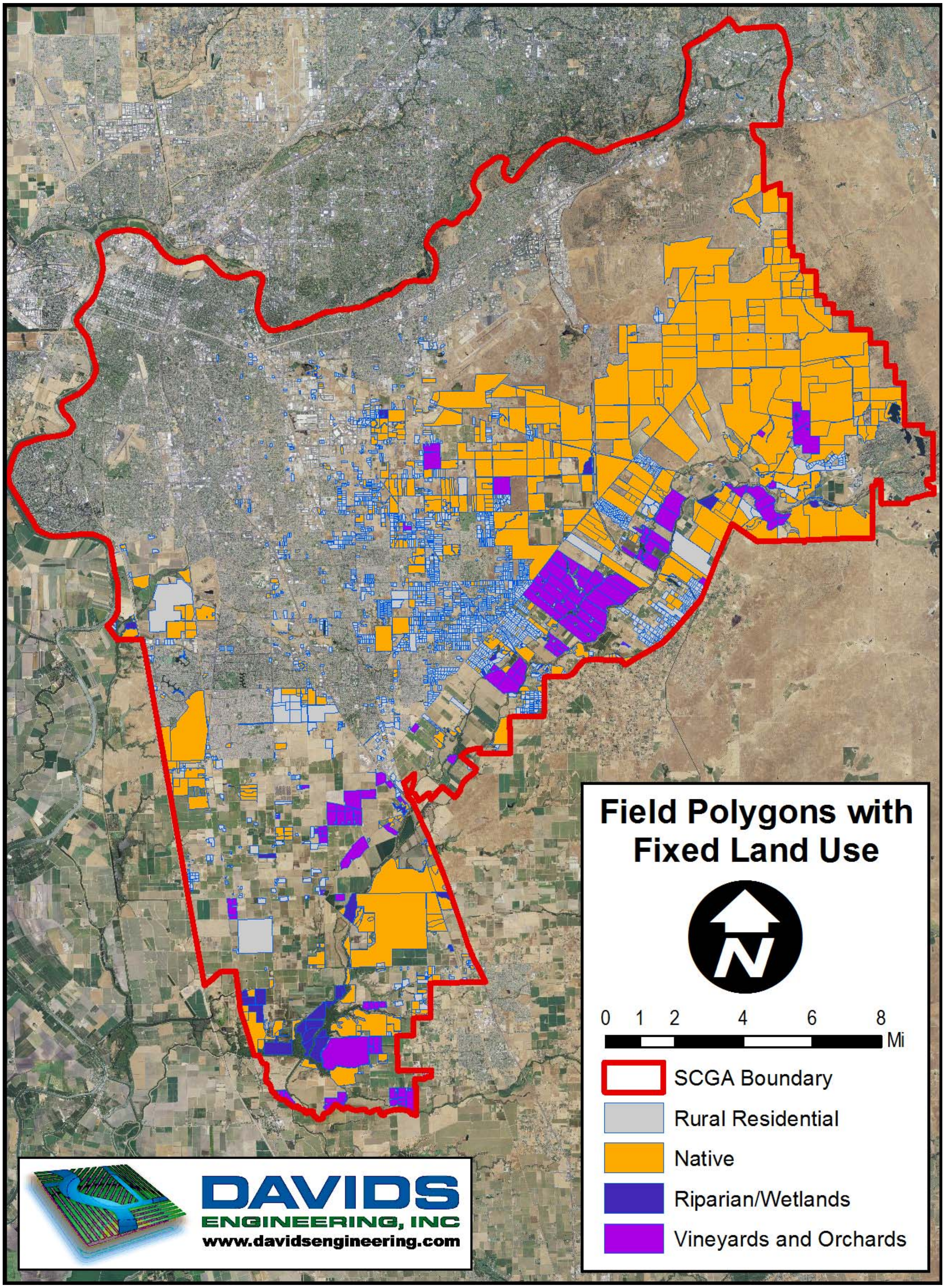


Figure 2. Field Polygons with Fixed Land Use.

Development of 2011 Land Use

This section describes land use assignment for 2011.

Initial Land Use Assignment

Land use for 2011 was estimated for each field polygon as follows:

1. Extract land use data by CDL pixel for each field polygon using ArcGIS Spatial Analyst.
2. Reclassify 2011 CDL to SCGA land use classes in MS Access.
3. Identify the SCGA land use class of majority for each polygon in MS Access.
4. For field polygons with fixed land use (3,095 field polygons comprising a total of 71,799 acres), as described above, assign 2008 SACOG land use class.
5. For field polygons that are too small to contain CDL pixels (311 field polygons comprising a total of 70 acres), assign 2008 SACOG land use class.
6. For remaining field polygons (1,659 field polygons comprising a total of 42,134 acres), assign the SCGA land use class of majority (from step 3).

Validation and Refinement of Land Use Assignment

Following the initial land use assignment, the following steps were completed to validate and refine the results:

1. Select polygons without a fixed land use and without a crop covering at least 80% of each polygon (based on 2011 CDL assigned land use). Visually inspect available aerial and satellite imagery.

   This resulted in identification of 18 fields making up 494 acres. Land use assignments for 2011 were modified from fallow to an agricultural land use for six fields based on review of available Landsat (Clark et al. 2014) and NAIP imagery.

2. Select polygons with at least 80% of a particular crop in 2011 that differs from 2008 SCGA land use class. Visually inspect available aerial and satellite imagery.

   This resulted in identification of 324 fields comprising 11,514 acres. Of these, 188 fields 20 acres or more comprising a total of 10,378 acres were visually inspected, and 2011 SCGA land use was updated for 34 fields. Common changes include crop rotation from a pasture or hay crop to a field or truck crop or idle or vice-versa.

Development of 2012 Land Use

This section describes land use assignment for 2012.

Initial Land Use Assignment

Land use for 2012 was estimated for each field polygon as follows:

1. Extract land use data by CDL pixel for each field polygon using ArcGIS Spatial Analyst.
2. Reclassify 2012 CDL to SCGA land use classes in MS Access.
3. Identify the SCGA land use class of majority for each polygon in MS Access.
4. For field polygons with fixed land use (3,095 fields comprising a total of 71,799 acres), as described above, assign 2008 SACOG land use class
5. For fields too small to contain CDL pixels (311 fields comprising a total of 70 acres), assign 2008 SACOG land use class.
6. For remaining fields (1,659 fields comprising a total of 42,134 acres), assign the 2012 SCGA land use class of majority (from step 3).

Validation and Refinement of Land Use Assignment

Following the initial land use assignment, the following steps were completed to validate and refine the results:

1. Select polygons without a fixed land use and without a crop covering at least 80% of each polygon (based on 2012 CDL assigned land use). Visually inspect available aerial and satellite imagery.

   This resulted in identification of 12 fields making up 219 acres. Land use assignments for 2012 were modified from fallow to an agricultural land use for three fields based on review of available Landsat and NAIP imagery.

2. Select polygons with at least 80% of a particular crop in 2012 that differs from 2011 SCGA land use class. Visually inspect available aerial and satellite imagery.

   This resulted in identification of 188 fields comprising 5,222 acres. Of these, 97 fields 20 acres or more comprising a total of 4,455 acres were visually inspected, and 2012 SCGA land use was updated for 24 fields. Common changes include crop rotation from a pasture or hay crop to a field or truck crop or idle or vice-versa.

Land Use Summary

Results of the land use analysis are presented in Table 3, Figure 3, and Figure 4. Table 3 presents estimated acreages by year for each land use class. 2011 and 2012 land use conditions are shown in Figure 3 and Figure 4, respectively. The combined percent change for agricultural land uses, other than fallow was less than one percent. In general, acreages for cropland other than pasture and hay decreased from 2011 to 2012. For non-crop land use classes, acreage remained nearly the same, with an increase in acreage for Riparian/Wetlands resulting from development of managed wetlands on lands previously cropped north of Thornton in the southwest corner of SCGA.

Table 3. Summary of 2011 and 2012 SCGA Land Use.

SCGA Land Use Class	Acreage by Year 2011	Acreage by Year 2012	Percent Change
Fallow	1,838	1,423	-23%
Field and Truck	8,568	7,166	-16%
Pasture and Hay	30,346	32,073	6%
Vineyards and Orchards	9,175	9,036	-2%
Native	48,477	48,477	0%
Riparian/Wetlands	1,721	1,873	9%
Rural Residential	13,878	13,955	1%

Acreages for several land use classes differ substantially from the 2008 SACOG data. This results from actual changes in land use and from differences in land use assignment between the SACOG and current efforts. Review of metadata for the SACOG 2008 land use data suggests that land use types for cropland were developed primarily based on 2006 agricultural commissioner Pesticide Use Reporting (PUR) data. Many fields not applying agrichemicals may not be included in the PUR database. By updating the land use data for 2011 and 2012 based on the FMMP and the Fine-Scale Riparian Vegetation Mapping by CDFW, it is believed that the 2011 and 2012 estimated acreages are more accurate than those of 2008 SACOG land use in the Study Area.

Specifically, changes from the 2008 SCGA land use include:

- A decrease in fallow area by approximately 2,000 acres,
- A decrease in field and truck area by approximately 2,000 acres,
- An increase in pasture and hay area by approximately 7,000 acres,
- An increase in native area by approximately 2,000 acres,
- A decrease in riparian/wetlands area by approximately 7,000 acres,
- An increase in rural residential area by approximately 2,000 acres, and
- An increase in vineyards and orchards area by approximately 1,000 acres.

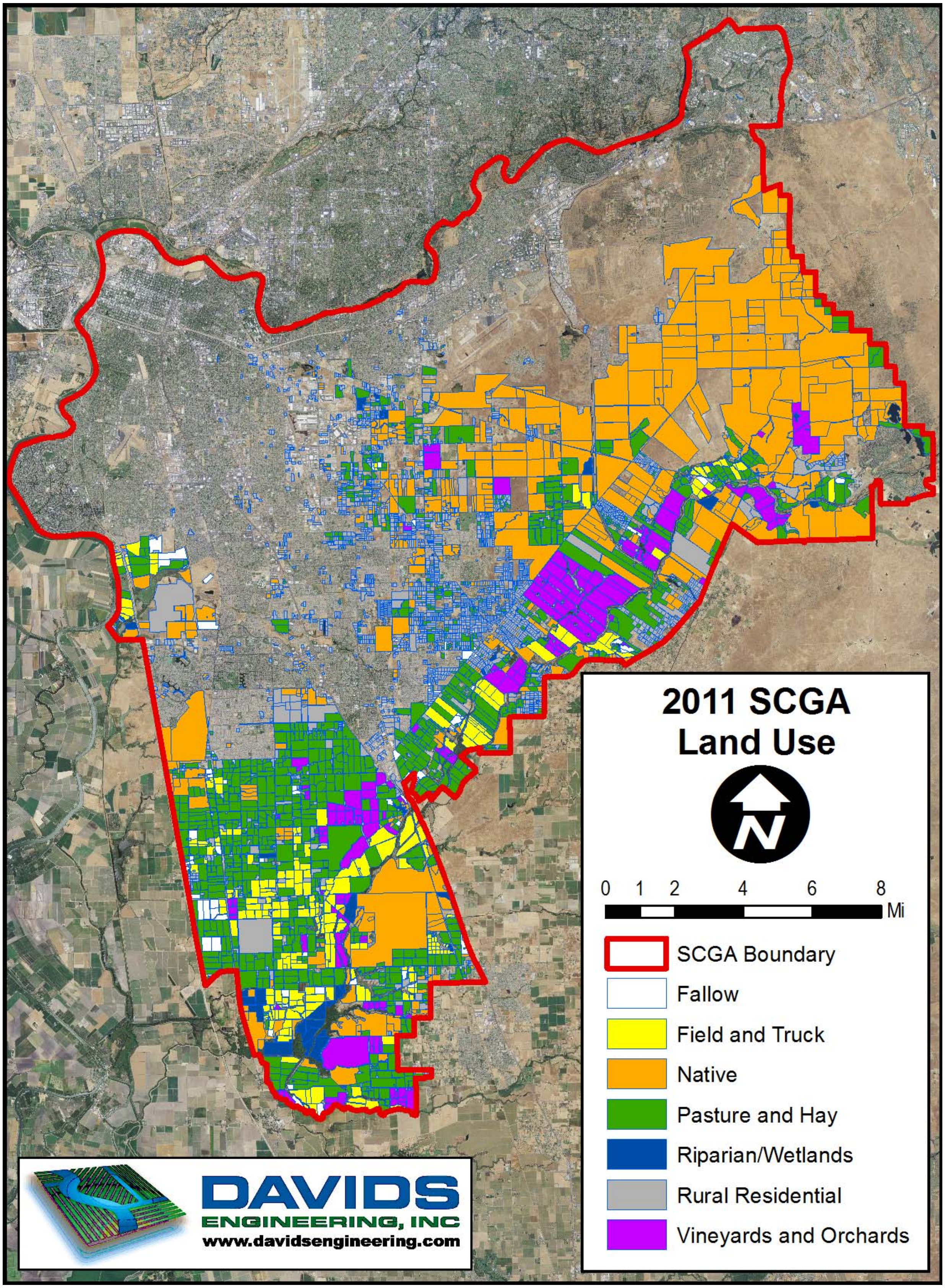


Figure 3. 2011 SCGA Land Use.

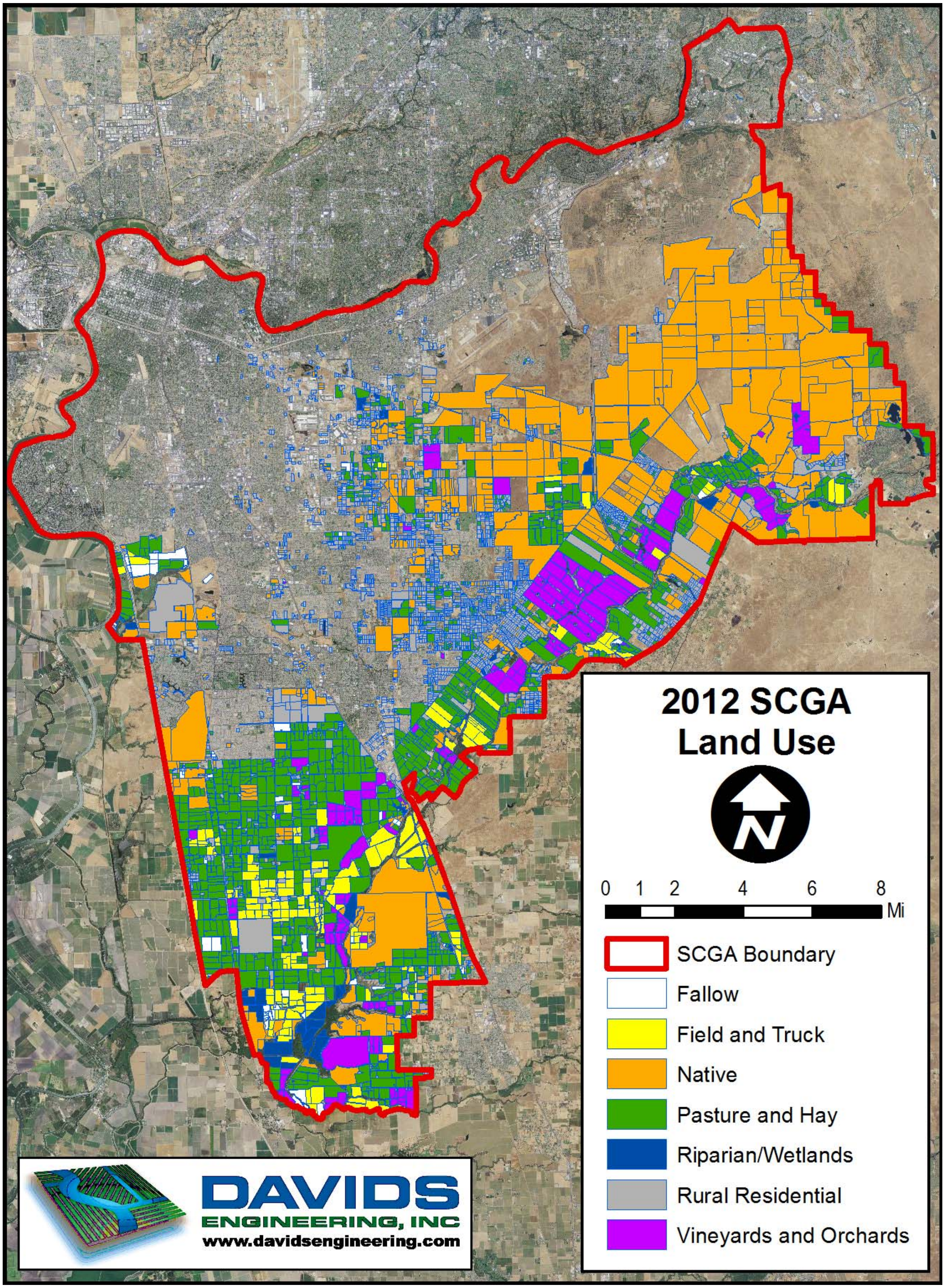


Figure 4. 2012 SCGA Land Use.

Parameterization of IWFM Demand Calculator and Agricultural Water Demand Estimates

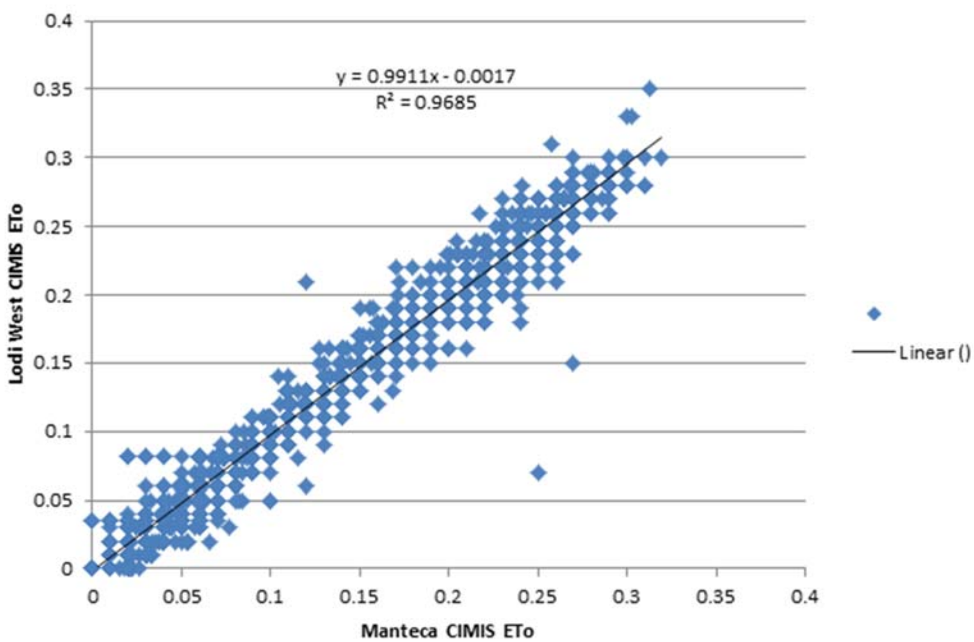
This section describes parameters used for IWFM Demand Calculator and agricultural water demand estimates in the SCGA study area.

Development of ET Estimates

Crop consumptive use or evapotranspiration (ET) was estimated using a crop coefficient-reference evapotranspiration calculation approach as described by Allen et al. (1998). In this approach, time-varying crop-specific coefficients describing crop ET relative to grass reference ET are estimated and multiplied by reference ET (ET_o) from an agronomic weather station to calculate ET for each crop over time. This section describes the analysis to develop time varying ET estimates by agricultural land use class (including rural residential) through the development of a quality-controlled reference ET time series for 2011 – 2012 as well as crop coefficients representing actual ET rates in the Study Area.

Reference ET

ET_o was estimated based on the California Irrigation Management Information System (CIMIS) Lodi West weather station (#166), located approximately 7 miles south of the Study Area[2]. Quality control procedures as described by Allen et al. (2005) were applied, including detailed review of weather parameters used to calculate ET_o such as solar radiation, temperature, relative humidity, and wind speed. All available weather parameters used to compute ET_o appeared to be reliable; however, ET_o data for the period from 11/12/2012 to 12/31/2012 were not reported and were estimated through correlation to quality-controlled daily ET_o data from the Manteca CIMIS station (#70), as shown in Figure 5. Monthly ET_o values for the Lodi West station are shown in Figure 6.



[2] Additional information is available at http://wwwcimis.water.ca.gov/cimis/welcome.jsp.

Figure 5. Correlation of Lodi West ET_o to Manteca ET_o (inches per day).

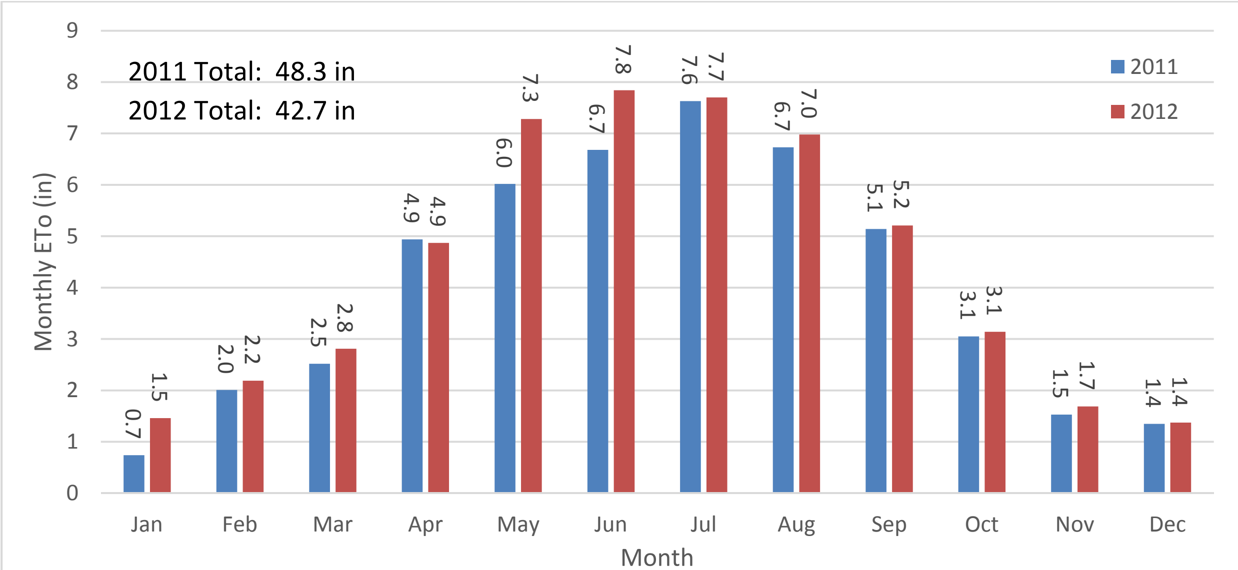


Figure 6. Lodi West Daily and Monthly ET_o, 2011 – 2012.

Crop Coefficients

Crop coefficients are different in primary growing season and winter period and were calculated separately.

Crop Coefficients for Primary Growing Season

Crop coefficients during the growing season were developed based on available Surface Energy Balance Algorithm for Land (SEBAL, Bastiaanssen et al., 2005) data describing actual ET (ET_a) for the 2009 growing season. The SEBAL data were developed as part of a study conducted for the California Department of Water Resources (DWR) to evaluate ETa rates in the Sacramento-San Joaquin River Delta to improve estimates of ET in the Delta (SNA 2012). Eight Landsat satellite images spanning the March to September primary growing season were analyzed with SEBAL to develop monthly estimates of ET_a by image pixel (approximately 0.25 acres). The Study Area is part of the area covered in the Landsat satellite images. A map showing SEBAL estimated ET_a for March to September 2009 is shown in Figure 7.

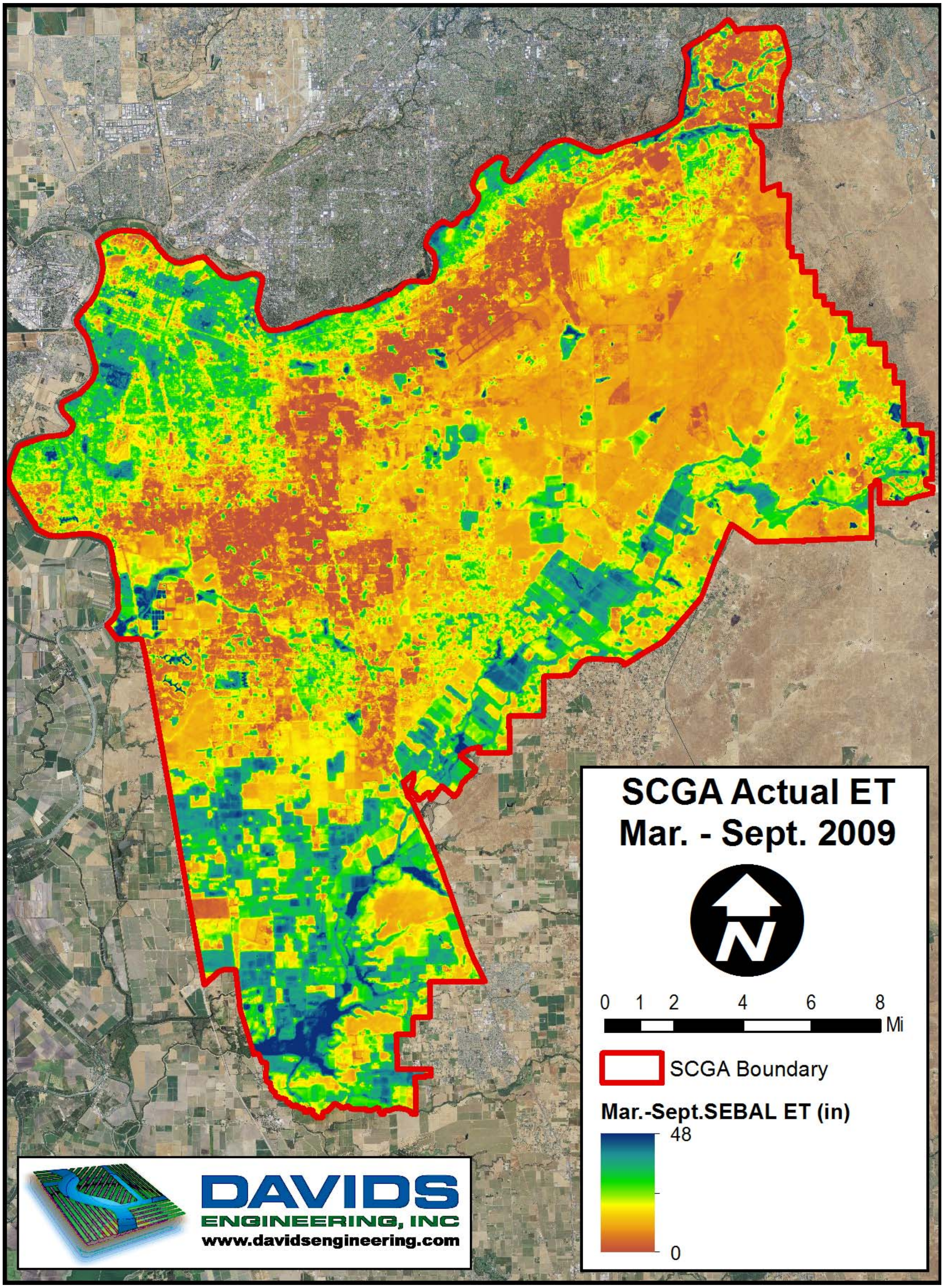


Figure 7. SCGA Actual ET, March – September 2009.

Cropping for each field polygon in 2009 was estimated based on the 2009 CDL. For field polygons with fixed land use, as described in the previous section, the fixed land use was used. For the remaining field polygons, the major SCGA land use class identified for each field polygon was assigned.

Average monthly ETa was extracted for each field polygon. Then, monthly crop coefficients for each SCGA land use class were calculated for each month on a field-by-field basis dividing total ETa by the total ETo from the Lodi West CIMIS station.

Monthly crop coefficients for Field and Truck crops (which are dominated by corn based on the 2008 SACOG data) are shown in Figure 8. Seventy-three fields representing 2,903 acres were evaluated. The figure provides the monthly area-weighted mean crop coefficients, along with the 10^{th} and 90^{th} percentile values. The figure shows that crop coefficients vary widely across the fields evaluated. To demonstrate the variability among fields further, Figure 9 was created to show monthly crop coefficients for ten randomly selected Field and Truck fields are shown in Figure 9.

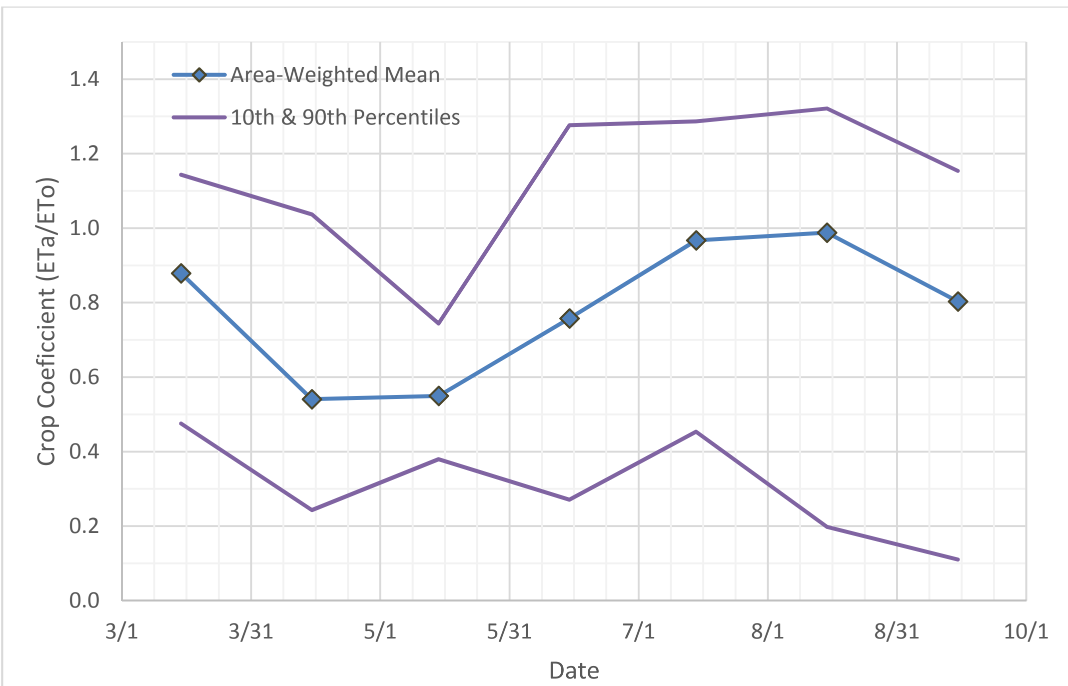


Figure 8. Monthly Crop Coefficients for Field and Truck Crop Fields (73 Fields Evaluated).

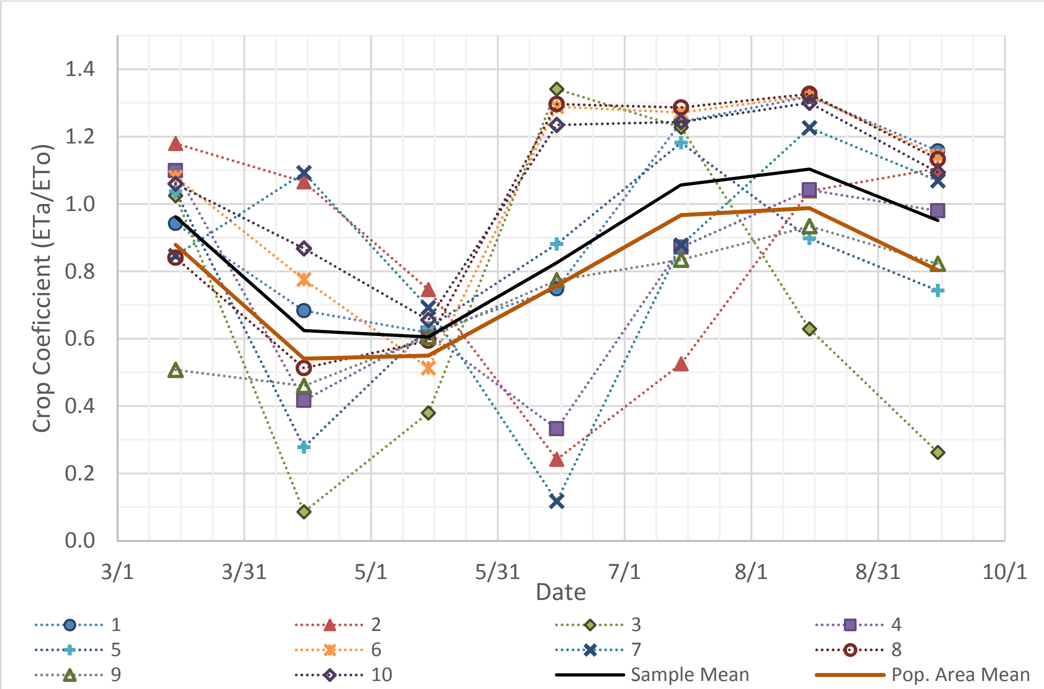


Figure 9. Monthly Crop Coefficients for Randomly Selected Field and Truck Crop Fields.

In general, the fields follow a similar pattern with relatively high crop coefficients in March representing winter grain crops, weeds, or wet soil conditions, followed by a decrease prior to planting in the spring, and a corresponding increase into July, August, and September, prior to harvest in October. Field 3 shows a different pattern with a peak crop coefficient in June, followed by decreasing values through September. While some other fields exhibit a pattern that would suggest a winter grain crop followed by corn, such as Fields 6, 8, and 10; Field 3 may have been cropped with safflower or another similar crop. By calculating the area-weighted average crop coefficient for each SCGA land use, potential biases in ET estimates resulting from variability among fields due to different crops in the same land use class can be minimized, assuming that the proportion of area in different crops within a class is relatively consistent from year to year.

Crop Coefficients for Winter Period

Crop coefficients during the winter period were estimated using the Basic Irrigation Scheduling (BIS) tool developed by Dr. Richard Snyder at U.C. Davis in cooperation with DWR[3]. The tool can be used to develop bare soil crop coefficient values based on ET_o and precipitation estimates. The assumption of bare soil conditions during the winter provides a reasonable estimate of winter crop coefficient values because precipitation coupled with relatively low ET_o tends to result in relatively wet conditions and high crop coefficients. These coefficients are similar to what would be expected for crops with vegetation present in the winter such as grain or pasture. Variability in precipitation patterns from year to year could result in variability in winter crop coefficients, but these differences are expected to have limited influence on estimated applied water and pumping estimates.

[3] The BIS tool is available at http://biomet.ucdavis.edu/irrigation_scheduling/bis/BIS.htm.

Average monthly values of ET_o and precipitation for 2001 to 2013 were used to estimate long term average winter crop coefficients for the Study Area. The estimated crop coefficients for winter period (October to February) are shown in Figure 10.

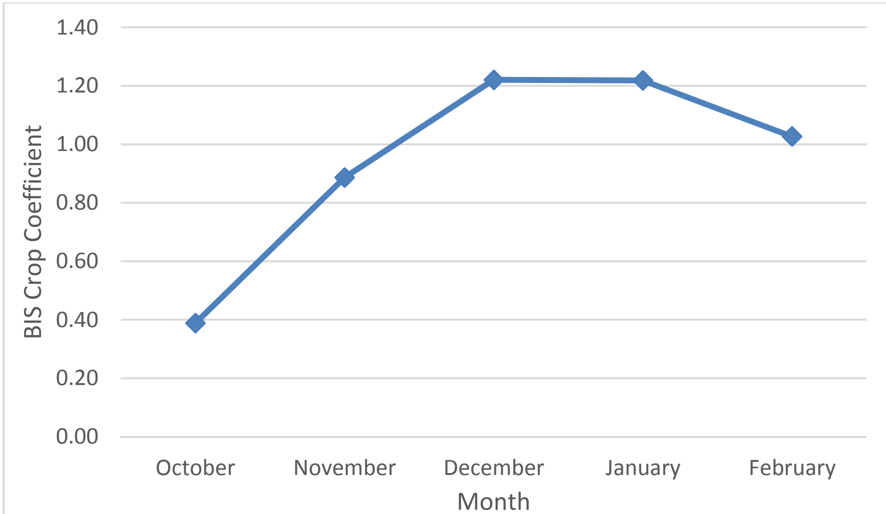


Figure 10. Winter Crop Coefficients for Study Area.

Summary

Estimated monthly crop coefficients for SCGA land use classes are summarized in Table 4 and Figure 11. For land use types that are typically irrigated or have water available (e.g., Riparian/Wetlands) through October, it is assumed that the September crop coefficients are representative of conditions in October, rather than the BIS crop coefficients, which assume bare soil conditions.

Table 4. Estimated Monthly Crop Coefficients for SCGA Land Use Classes.

Land Use	Monthly Crop Coefficient											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fallow	1.22	1.03	0.99	0.71	0.40	0.21	0.11	0.13	0.12	0.39	0.89	1.22
Field and Truck	1.22	1.03	0.88	0.54	0.55	0.76	0.97	0.99	0.80	0.60	0.89	1.22
Native	1.22	1.03	0.92	0.75	0.56	0.16	0.09	0.10	0.16	0.39	0.89	1.22
Pasture and Hay	1.22	1.03	1.04	0.88	0.67	0.53	0.51	0.54	0.56	0.56	0.89	1.22
Riparian/Wetlands	1.22	1.03	1.03	0.99	0.81	0.78	0.67	0.65	0.63	0.63	0.89	1.22
Rural Residential	1.22	1.03	0.86	0.70	0.52	0.29	0.18	0.20	0.33	0.39	0.89	1.22
Vineyards and Orchards	1.22	1.03	0.82	0.54	0.65	0.71	0.69	0.72	0.81	0.81	0.89	1.22

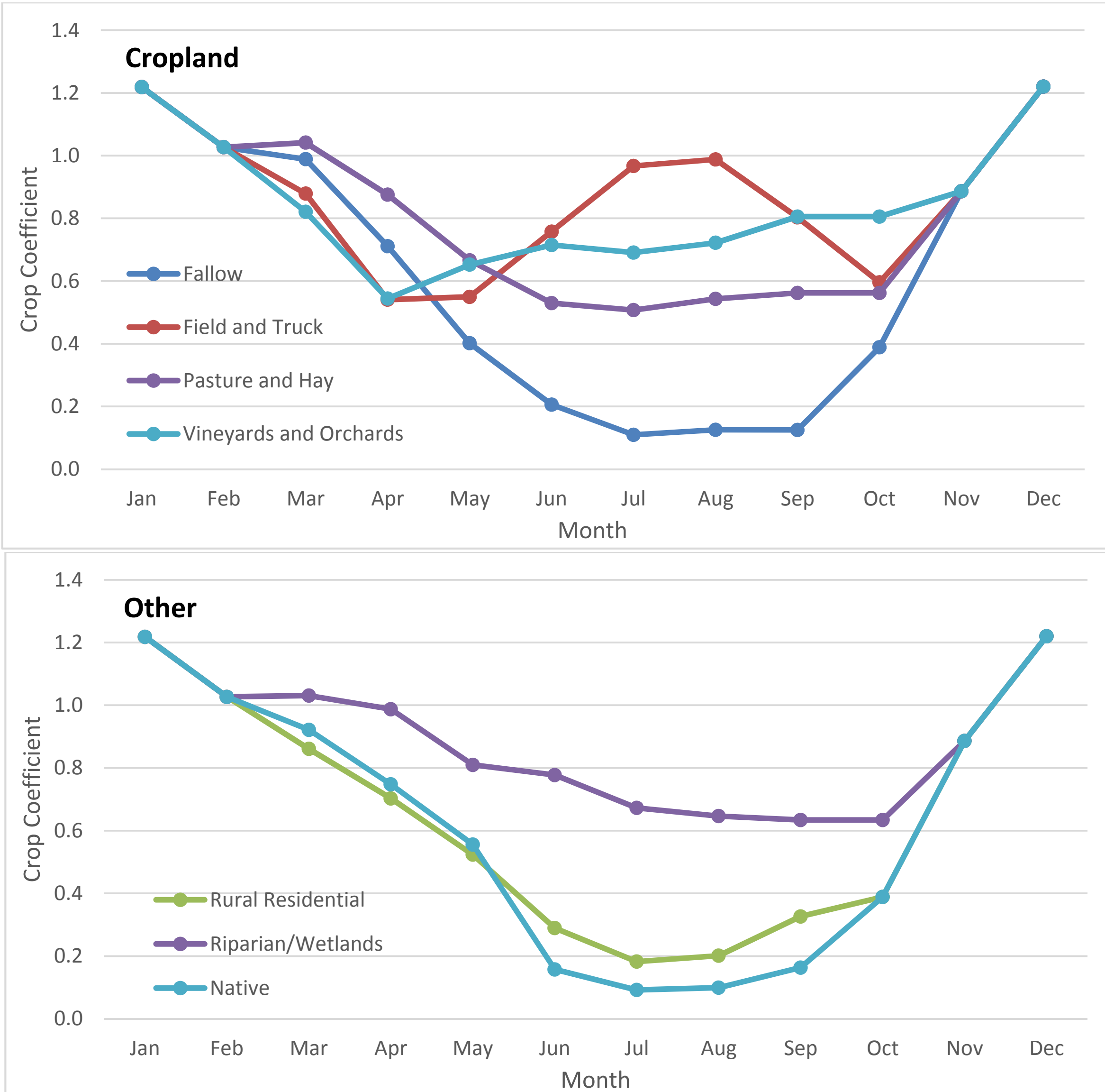


Figure 11. Estimated Monthly Crop Coefficients for SCGA Land Use Classes.

As expected, the crop coefficient for Fallow declines to around 0.1 by July and remains relatively low throughout the summer months indicating very limited soil moisture availability. The Pasture and Hay crop coefficient declines to approximately 0.5 by June and remains at this level for the remainder of the summer, reflecting a combination of partially irrigated, fully irrigated, and non-irrigated fields. This observation is supported by review of available mid-summer aerial imagery. Applying this crop coefficient to the full Pasture and Hay area provides a reasonable estimate of the water applied to the total area. Both Vineyard and Orchard and Field and Truck crop coefficients appear reasonable based on general knowledge of irrigation practices and considering the variability among fields.

The Rural Residential and Native areas have crop coefficients very similar to the fallowed land as expected for generally non-irrigated areas. The Rural Residential crop coefficients are somewhat greater than Fallow or Native classes during mid-summer, reflecting partially irrigated or fully irrigated parcels. The Riparian/Wetlands crop coefficient indicates increased water availability as compared to Native areas, which consist primarily of annual grasslands, due to the access of riparian and wetland vegetation to shallow groundwater and potentially some runoff (if any) from upgradient lands. Availability of moisture declines over the course of the growing season, as indicated by decreasing crop coefficients.

Development of Precipitation Estimates

Daily precipitation within the Study Area was estimated based of precipitation records from the Elk Grove Fish Hatchery, available from the California Data Exchange Center (CDEC)[4]. The hatchery is located on the north side of Bond Road, approximately 0.7 miles east of Highway 99 in the Study Area. Reported daily precipitation amounts were reviewed to identify extreme and missing values. Extreme values were flagged based on daily precipitation amounts greater than five inches. Missing values were filled based on precipitation reported for the Lodi West CIMIS station. During 2011, no extreme values and one missing value were identified. During 2012, no extreme values and seven missing values were detected. For the total eight missing daily values in 2011 and 2012, reported precipitation at the Lodi West CIMIS station was zero for all days. These results suggest the Elk Grove Fish Hatchery precipitation values are a relatively reliable source of precipitation data for the area. Quality controlled monthly precipitation estimates for 2011 and 2012 are shown in Figure 12.

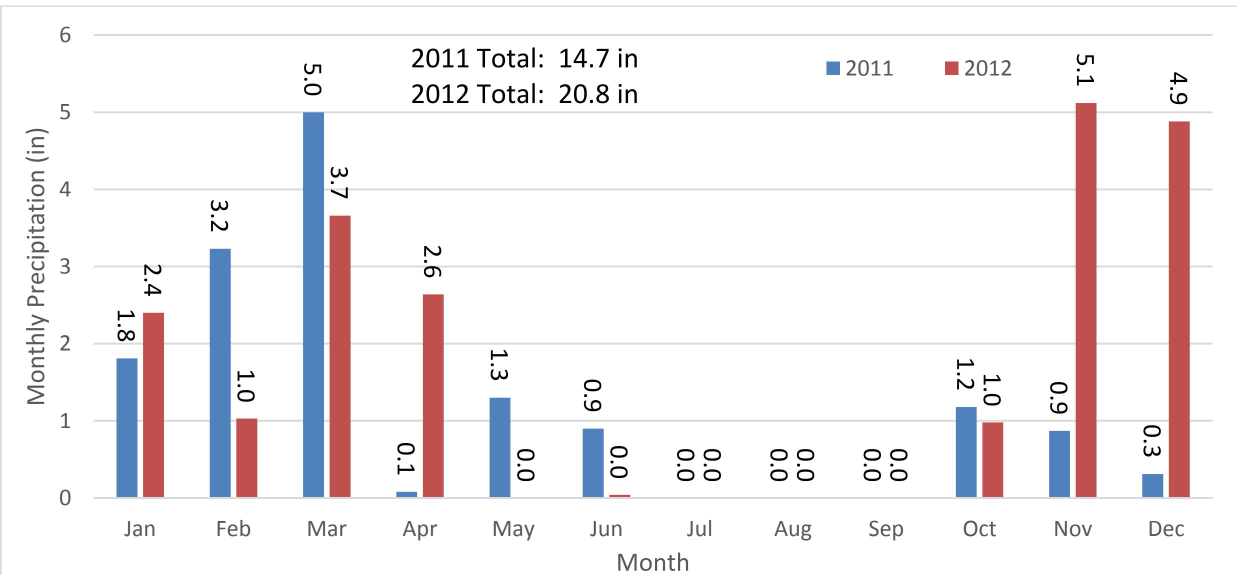


Figure 12. Monthly Precipitation at Elk Grove Fish Hatchery, 2011 – 2012.

Assignment of Soil Types and Estimation of Soil Hydraulic Parameters, Crop Rooting Depths, and Irrigation Efficiencies

This section describes other parameters used for agricultural groundwater pumping estimates, including soil types, soil hydraulic parameters, root depths, and irrigation efficiencies.

[4] Data is available at http://cdec.water.ca.gov/.

Soil Parameters

Soil types were assigned to each field polygon based on the majority-soil-map unit from the Natural Resources Conservation Service (NRCS, formerly Soil Conservation Service) soil survey of Sacramento County (SCS 1993). Each soil was assigned to a USDA soil texture class based on depth-weighted sand, silt, and clay percentages identified in the soil survey. Based on this assignment, four unique soil classes were selected to represent the Study Area. Soil groups and corresponding USDA texture classes are summarized in Table 5.

Table 5. SCGA Soil Groups, USDA Texture Classes and Sand-Silt-Clay Percentages.

Soil Group	USDA Soil Texture	Acres	Sand %	Silt %	Clay %
1	clay	11,538	23	29	48
	clay loam	29,091	33	36	31
2	loam	16,624	40	40	21
3	sandy clay loam	3,310	56	21	23
	sandy loam	7,076	67	19	14
4	silt loam	43,621	18	69	14
	silty clay loam	1,023	19	50	30

For each soil group, volumetric water content at the wilting point, field capacity, and saturation were estimated based on the pedotransfer functions described by Saxon and Rawls (2006) as well as saturated hydraulic conductivity (K_{sat}) and pore size distribution index (λ [lambda]). In order to achieve reasonable estimates of deep percolation, it has been shown to be necessary to modify K_{sat} and λ (Thoreson 2014). The use of default values as estimated based on Saxon and Rawls results in soil moisture content in the root zone above field capacity for extended periods (slow drainage). The parameters were adjusted to meet the following objectives:

- Drainage from saturation to field capacity in a reasonable amount of time for a given soil texture.
- Drainage from saturation to nearly field capacity in three days.
- Negligible drainage once field capacity is reached.

Estimated soil hydraulic parameters for each soil group are summarized in Table 6.

Table 6. Soil Hydraulic Parameters for SCGA Soil Groups.

Soil Group	Volumetric Water Content			K_{sat} (ft/d)	Lambda	Hydrologic Soil Group
	Saturation	Field Capacity	Wilting Point			
1 (Clay Loam)	0.44	0.35	0.22	0.22	0.16	C
2 (Loam)	0.40	0.26	0.13	10.00	0.16	A
3 (Sandy Loam)	0.38	0.19	0.10	14.00	0.32	D
4 (Silt Loam)	0.39	0.28	0.09	3.50	0.13	C

Crop Rooting Depths

Rooting depths were estimated based on literature review and experience from past projects (Allen et al. 1998, Keller and Bliesner 2000). Assigned rooting depths by SCGA land use class are summarized in Table 7.

Table 7. Assigned Rooting Depths for SCGA Land Use Classes

SCGA Land Use Class	Rooting Depth (feet)
Fallow	3.0
Field and Truck	3.5
Native	4.0
Pasture and Hay	3.5
Riparian/Wetlands	4.0
Rural Residential	2.5
Vineyards and Orchards	4.0

Surface Runoff

IDC Version 4.0 simulates runoff of surface water from precipitation and irrigation. Runoff from precipitation is estimated using the NRCS curve number method, with the calculations modified to be applied on a daily basis rather than for individual precipitation events. Runoff from irrigation (tailwater) is specified as a fraction of the applied water amount for each irrigated land use type. For this analysis, the following curve numbers were estimated by hydrologic soil group (Table 8).

Table 8. Estimated NRCS Curve Numbers by SCGA Land Use Class and Hydrologic Soil Group.

SCGA Land Use Class	Hydrologic Soil Group		
	A	C	D
Fallow	77	91	94
Field and Truck	67	85	89
Native	30	65	73
Pasture and Hay	30	71	78
Riparian/Wetlands	30	65	73
Rural Residential	59	82	86
Vineyards and Orchards	32	72	79

Available data describing stream flows in the region include public sources, prior field studies by Davids Engineering on Willow Creek and Badger Creek, and observed summer flows in the Cosumnes River at Highway 99. Based on the knowledge gained from these data, it is believed that little runoff from irrigation, if any, leaves the area during the primary growing season. Instead, any tail water generated is likely recovered and reused for irrigation; it may seep from drains or streams into the groundwater system; or it may be consumed as ET by riparian, wetlands, or native vegetation. Therefore, IDC was configured assuming no runoff from irrigation.

Consumptive Use Fraction and Target Soil Moisture Fraction

Estimates of the consumptive use fraction (CUF), which is defined as the ratio of ET of applied water to applied water and is analogous to irrigation efficiency when other beneficial uses are not considered, were used to parameterize IDC to estimate applied water amounts. In IDC Version 4.0, the amount of applied water for a simulated irrigation event is determined based on a target soil moisture fraction (TSMF), which is the desired soil water content following irrigation, defined as a fraction of field capacity. TSMF values by crop were estimated iteratively in IDC to achieve average target CUF values for all soil types in 2011 and 2012. CUF values are allowed to vary for different soil groups based on their relative hydraulic properties and their corresponding drainage rates. CUF values are expected to vary across years based on precipitation patterns and corresponding irrigation management considerations. Estimates of typical CUF values have been compiled from the following sources:

- Estimates developed by Davids Engineering from prior water balance analyses in the Sacramento and San Joaquin Valleys
- “Agricultural Water Use in California: A 2011 Update” by Canessa et al. (2011)

Estimates of CUF by crop group are summarized in Table 9, along with selected TSMF and modelled CUF values. CUF values are assumed to be marginally greater for groundwater-only areas as compared to estimated values for areas supplied primarily by surface water. Modelled CUF values were obtained by calculating area-weighted averages of crop-soil groups in 2011 and 2012.

Table 9. Estimated CUF, TSMF, and Modelled CUF by Crop Group.

SCGA Land Use Class	Estimated CUF	TSMF	Modelled CUF
Field and Truck	0.70	1.09	0.72
Pasture and Hay	0.75	1.03	0.76
Rural Residential	0.65	1.07	0.64
Vineyards and Orchards	0.80	0.95	0.82

IWFM Demand Calculator Results

IDC Version 4.0 was configured and run on a daily time step for the period from January 1, 2009 to December 31, 2012. Starting the simulation before the beginning of 2011 allowed the model to “runup” or condition initial soil moisture conditions based on precipitation and atmospheric water demand prior to the period of interest. The model was configured on a unitized basis to develop estimates of surface layer fluxes for each unique land use class and soil group combination. The irrigation period for each irrigated land use was approximated as follows:

- Field and Truck – March through September
- Pasture and Hay – March through October
- Rural Residential – May through October
- Vineyards and Orchards – March through October

The model was configured so that no irrigation occurred until May for Rural Residential irrigation to avoid overestimation of annual applied water volumes. The overestimation could occur because the Rural Residential area consists of both irrigated and non-irrigated areas. For the non-irrigated areas, the crop coefficients depend on the amount and temporal distribution of rainfall. Therefore, if rainfall in the winter months is less than that of an average year, the applied water volume may be overestimated. The effects of irrigation are demonstrated in Figure 11, which indicates that the crop coefficients for Rural Residential increased compared to native grasses in the summer months. The crop coefficients for these two land use classes are nearly the same for January through May because precipitation and stored precipitation is typically sufficient to sustain ET until June. It is likely that some irrigation occurred in the rural residential area in March and April; however, IDC tends to overestimate these amounts if configured to simulate irrigation for full parcels. Monthly pumping estimates of rural residential pumping could be refined through an analysis to quantify the rural residential land area that is green during mid-summer. This could be accomplished using readily available Normalized Difference Vegetation Index (NDVI) data from Landsat satellites.

Calendar year summary results for a typical Field and Truck crop (e.g., corn) field on clay loam (Group 1) soils are provided in Table 10. Sample daily simulation results for Field and Truck crops on clay loam (Group 1) soils are provided in Figure 13. Monthly results are provided in Figure 14. The following symbols are used in the Table and Figures:

- AW – Applied Water
- Pr – Precipitation
- ET_{aw} – ET of Applied Water
- ET_{pr} – ET of Precipitation
- DP_{aw} – Deep Percolation of Applied Water
- DP_{pr} – Deep Percolation of Precipitation
- RO – Surface Runoff
- CUF—Consumptive Use Fraction

Table 10. Calendar Year Summary Results for Field and Truck Crops on Loam Soils.

Year	AW (in)	Pr (in)	ET (in)	ET_{aw} (in)	ET_{pr} (in)	DP_{aw} (in)	DP_{pr} (in)	RO (in)	CUF
2011	41.1	14.7	38.9	26.7	12.2	13.7	6.2	0.2	0.65
2012	46.2	20.8	41.5	32.5	9.0	15.4	5.5	1.0	0.70

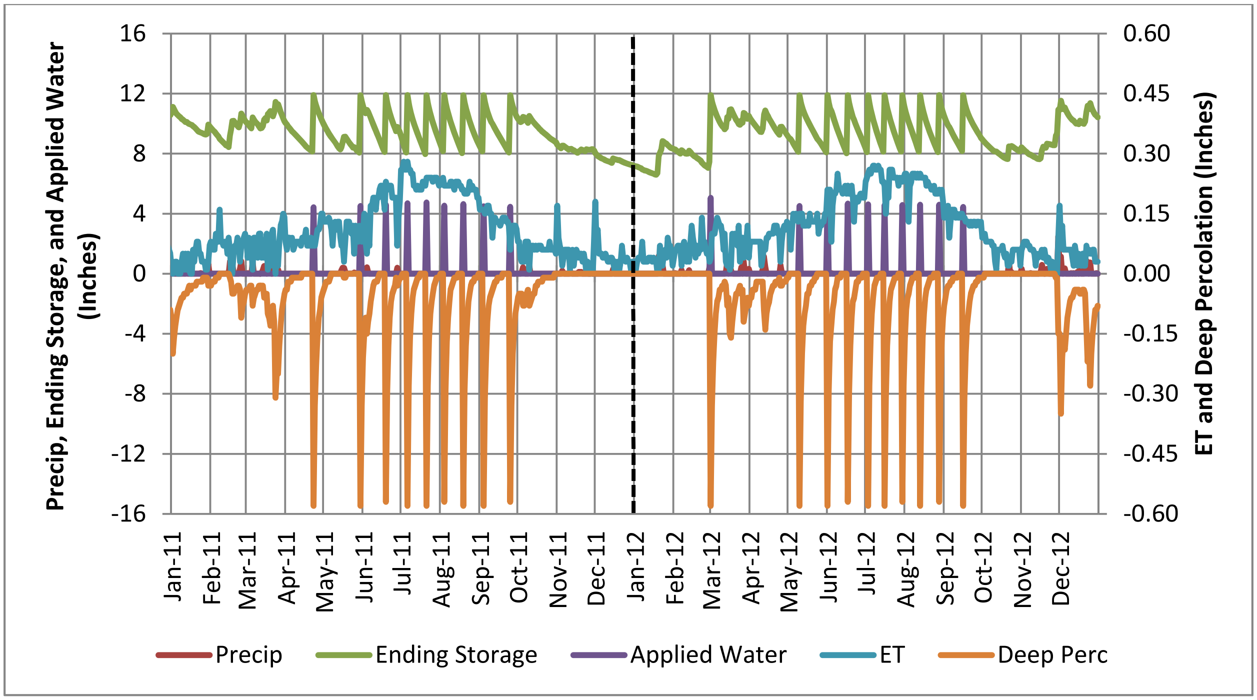


Figure 13. IDC Daily Simulation Results for Typical Field and Truck Crop Field on Loam Soils.

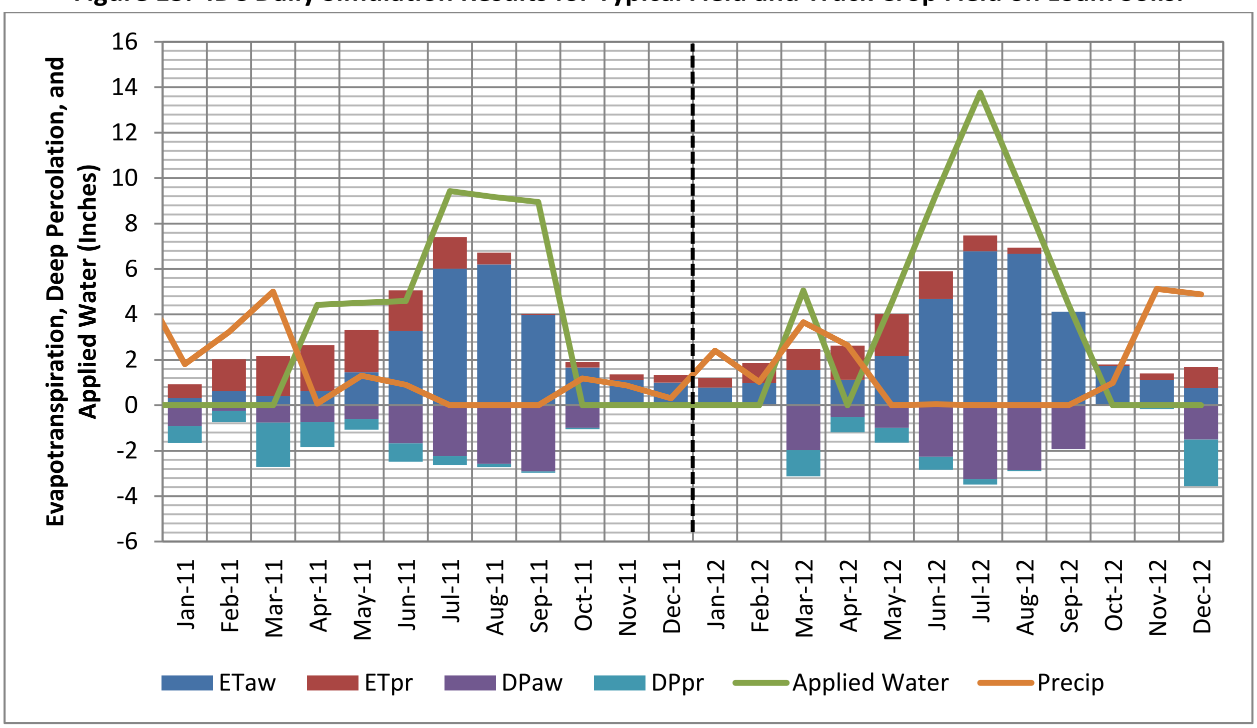


Figure 14. IDC Monthly Simulation Results for Typical Field and Truck Crop Field on Loam Soils.

The patterns of ET, applied water, and deep percolation resulting from the IDC simulation appear reasonable. The exception is that there is limited irrigation during the winter period because irrigation of winter grain crops may occur preceding summer corn (or other field crops), or for frost protection or other purposes (depending on crop). Irrigation generally occurs between April and September in order to meet ET demands and replenish soil moisture depletion by the crop. Irrigation requirements in 2012 were somewhat greater than in 2011 because of less water stored from precipitation in the root zone at the beginning of the primary growing season.

Annual IDC results expressed in inches for all irrigated land use classes are provided in Tables 11 and 12 for 2011 and 2012, respectively. Annual IDC results expressed in acre-feet are provided in Tables 13 and 14 for 2011 and 2012, respectively.

Table 11. Annual IDC Results for Irrigated Land Use Classes, 2011 (inches).

SCGA Land Use	Acres	Surface Layer Fluxes (inches)							CUF
		AW	Pr	ET_{aw}	ET_{pr}	DP_{pr}	DP_{aw}	RO	
Field and Truck	8,568	38.8	14.7	27.1	11.7	4.6	11.4	0.7	0.70
Pasture and Hay	30,346	26.7	14.7	19.3	12.9	4.6	6.9	0.7	0.72
Rural Residential	13,878	14.9	14.7	10.0	11.2	4.2	5.4	0.7	0.67
Vineyards and Orchards	9,175	27.8	14.7	21.8	13.9	4.4	5.5	0.8	0.79
Irrigated Land Uses	61,967	25.9	14.7	18.7	12.5	4.5	7.0	0.7	0.72

Table 12. Annual IDC Results for Irrigated Land Use Classes, 2012 (inches).

SCGA Land Use	Acres	Surface Layer Fluxes (inches)							CUF
		AW	Pr	ET_{aw}	ET_{pr}	DP_{pr}	DP_{aw}	RO	
Field and Truck	7,166	44.1	20.8	33.2	8.4	3.4	12.1	0.8	0.75
Pasture and Hay	32,073	31.2	20.8	24.6	10.4	3.9	7.8	0.8	0.79
Rural Residential	13,955	20.1	20.8	12.4	10.4	3.2	7.4	0.6	0.62
Vineyards and Orchards	9,036	33.1	20.8	28.2	10.6	3.4	6.2	0.9	0.85
Irrigated Land Uses	62,229	30.5	20.8	23.4	10.2	3.6	8.0	0.8	0.77

Table 13. Annual IDC Results for Irrigated Land Use Classes, 2011 (acre-feet).

SCGA Land Use	Surface Layer Fluxes (acre-feet)							CUF
	AW	Pr	ET_{aw}	ET_{pr}	DP_{pr}	DP_{aw}	RO	
Field and Truck	27,737	10,481	19,345	8,321	3,284	8,136	505	0.70
Pasture and Hay	67,531	37,123	48,888	32,589	11,614	17,512	1,864	0.72
Rural Residential	17,188	16,978	11,552	12,942	4,867	6,267	819	0.67
Vineyards and Orchards	21,243	11,224	16,704	10,625	3,326	4,192	612	0.79
Irrigated Land Uses	133,700	75,806	96,489	64,477	23,091	36,107	3,800	0.72

Table 14. Annual IDC Results for Irrigated Land Use Classes, 2012 (acre-feet).

SCGA Land Use	Surface Layer Fluxes (acre-feet)							CUF
	AW	Pr	ET_{aw}	ET_{pr}	DP_{pr}	DP_{aw}	RO	
Field and Truck	26,334	12,391	19,818	5,009	2,049	7,204	454	0.75
Pasture and Hay	83,312	55,459	65,698	27,794	10,331	20,976	2,145	0.79
Rural Residential	23,426	24,130	14,450	12,151	3,699	8,588	729	0.62
Vineyards and Orchards	24,941	15,625	21,243	8,000	2,541	4,658	654	0.85
Irrigated Land Uses	158,014	107,605	121,209	52,954	18,620	41,425	3,983	0.77

Monthly results for each irrigated land use class for 2011 and 2012 in units of depth are provided in Tables 15 through 18 and Tables 19 through 22, respectively. Due to the relatively small number of crop and soil combinations simulated in IDC, monthly patterns of ET_{aw} and DP_{aw} tend to be more representative of typical fields than large populations of fields in the Study Area. To approximate monthly pumping patterns and net depletion for the Study Area as a whole, annual estimates of applied water and estimates of deep percolation of applied water were distributed across the irrigation period for each irrigated land use based on monthly ET_{aw}.

Table 15. Monthly IDC Results for Field and Truck Crops, 2011 (inches).

Month	Surface Layer Fluxes (inches)						
	AW	Pr	ET_{aw}	ET_{pr}	DP_{pr}	DP_{aw}	RO
Jan-11	0.0	1.8	0.4	0.5	0.6	0.9	0.3
Feb-11	0.0	3.2	0.8	1.2	0.3	0.2	0.6
Mar-11	1.2	5.0	0.7	1.6	1.2	0.3	0.9
Apr-11	1.5	0.1	0.9	1.8	0.7	0.4	0.0
May-11	2.8	1.3	1.6	1.7	0.5	0.7	0.1
Jun-11	5.6	0.9	3.2	1.8	0.7	1.4	0.1
Jul-11	10.1	0.0	5.8	1.5	0.3	2.5	0.0
Aug-11	10.7	0.0	6.1	0.6	0.2	2.6	0.0
Sep-11	6.9	0.0	3.9	0.2	0.1	1.7	0.0
Oct-11	0.0	1.2	1.6	0.2	0.0	0.7	0.1
Nov-11	0.0	0.9	1.1	0.2	0.0	0.0	0.0
Dec-11	0.0	0.3	1.0	0.3	0.0	0.0	0.0
Annual	38.8	14.7	27.1	11.7	4.6	11.4	2.1

Table 16. Monthly IDC Results for Pasture and Hay, 2011 (inches).

Month	Surface Layer Fluxes (inches)						
	AW	Pr	ET_{aw}	ET_{pr}	DP_{pr}	DP_{aw}	RO
Jan-11	0.0	1.8	0.3	0.6	0.7	0.9	0.1
Feb-11	0.0	3.2	0.6	1.4	0.5	0.2	0.1
Mar-11	0.8	5.0	0.5	2.1	1.8	0.2	0.3
Apr-11	2.1	0.1	1.3	3.0	0.5	0.4	0.0
May-11	3.6	1.3	2.2	1.8	0.5	0.7	0.0
Jun-11	3.7	0.9	2.2	1.3	0.3	0.8	0.0
Jul-11	4.8	0.0	2.9	1.0	0.2	1.0	0.0
Aug-11	5.1	0.0	3.1	0.5	0.1	1.1	0.0
Sep-11	4.3	0.0	2.6	0.3	0.0	0.9	0.0
Oct-11	2.4	1.2	1.5	0.3	0.1	0.5	0.0
Nov-11	0.0	0.9	1.0	0.3	0.0	0.2	0.0
Dec-11	0.0	0.3	1.1	0.4	0.0	0.0	0.0
Annual	26.7	14.7	19.3	12.9	4.6	6.9	0.5

Table 17. Monthly IDC Results for Rural Residential, 2011 (inches).

Month	Surface Layer Fluxes (inches)						
	AW	Pr	ET_{aw}	ET_{pr}	DP_{pr}	DP_{aw}	RO
Jan-11	0.0	1.8	0.3	0.6	0.6	0.7	0.2
Feb-11	0.0	3.2	0.5	1.5	0.4	0.1	0.5
Mar-11	0.0	5.0	0.4	1.8	1.5	0.5	0.9
Apr-11	0.0	0.1	0.3	2.5	0.1	0.0	0.0
May-11	3.4	1.3	1.6	1.5	0.5	0.9	0.0
Jun-11	2.2	0.9	1.0	0.9	0.5	0.6	0.0
Jul-11	2.0	0.0	0.9	0.4	0.2	0.6	0.0
Aug-11	2.1	0.0	1.0	0.4	0.2	0.6	0.0
Sep-11	3.1	0.0	1.4	0.3	0.1	0.8	0.0
Oct-11	2.0	1.2	0.9	0.3	0.1	0.5	0.1
Nov-11	0.0	0.9	0.9	0.4	0.0	0.0	0.0
Dec-11	0.0	0.3	0.8	0.5	0.0	0.0	0.0
Annual	14.9	14.7	10.0	11.2	4.2	5.4	1.7

Table 18. Monthly IDC Results for Vineyards and Orchards, 2011 (inches).

Month	Surface Layer Fluxes (inches)						
	AW	Pr	ET_{aw}	ET_{pr}	DP_{pr}	DP_{aw}	RO
Jan-11	0.0	1.8	0.3	0.5	0.7	1.0	0.1
Feb-11	0.0	3.2	0.7	1.3	0.5	0.3	0.1
Mar-11	0.7	5.0	0.5	1.6	1.8	0.1	0.3
Apr-11	1.0	0.1	0.7	2.0	0.5	0.1	0.0
May-11	2.4	1.3	1.6	2.3	0.4	0.4	0.0
Jun-11	3.7	0.9	2.5	2.2	0.2	0.6	0.0
Jul-11	5.4	0.0	3.6	1.7	0.1	0.8	0.0
Aug-11	5.9	0.0	4.0	0.9	0.0	0.9	0.0
Sep-11	5.5	0.0	3.7	0.5	0.0	0.8	0.0
Oct-11	3.2	1.2	2.1	0.4	0.1	0.5	0.0
Nov-11	0.0	0.9	1.1	0.3	0.0	0.1	0.0
Dec-11	0.0	0.3	1.1	0.3	0.0	0.0	0.0
Annual	27.8	14.7	21.8	13.9	4.4	5.5	0.5

Table 19. Monthly IDC Results for Field and Truck Crops, 2012 (inches).

Month	Surface Layer Fluxes (inches)						
	AW	Pr	ET_{aw}	ET_{pr}	DP_{pr}	DP_{aw}	RO
Jan-12	0.0	2.4	0.9	0.4	0.0	0.0	0.3
Feb-12	0.0	1.0	1.0	0.8	0.0	0.0	0.0
Mar-12	2.7	3.7	1.7	0.8	0.8	0.7	0.7
Apr-12	2.2	2.6	1.4	1.3	0.5	0.6	0.6
May-12	3.8	0.0	2.4	1.6	0.5	1.0	0.0
Jun-12	7.6	0.0	4.7	1.2	0.4	1.9	0.0
Jul-12	10.6	0.0	6.6	0.8	0.2	2.7	0.0
Aug-12	10.6	0.0	6.6	0.3	0.1	2.7	0.0
Sep-12	6.6	0.0	4.1	0.1	0.0	1.7	0.0
Oct-12	0.0	1.0	1.8	0.0	0.0	0.0	0.2
Nov-12	0.0	5.1	1.1	0.3	0.0	0.1	1.5
Dec-12	0.0	4.9	0.9	0.8	1.0	0.8	1.0
Annual	44.1	20.8	33.2	8.4	3.4	12.0	4.3

Table 20. Monthly IDC Results for Pasture and Hay, 2012 (inches).

Month	Surface Layer Fluxes (inches)						
	AW	Pr	ET_{aw}	ET_{pr}	DP_{pr}	DP_{aw}	RO
Jan-12	0.0	2.4	0.8	0.5	0.0	0.0	0.1
Feb-12	0.0	1.0	1.0	1.0	0.0	0.0	0.0
Mar-12	2.5	3.7	1.7	1.2	0.7	0.5	0.2
Apr-12	2.6	2.6	1.8	2.5	0.5	0.5	0.1
May-12	4.2	0.0	2.8	2.0	0.3	0.8	0.0
Jun-12	4.8	0.0	3.2	0.9	0.2	0.9	0.0
Jul-12	5.1	0.0	3.4	0.5	0.1	1.0	0.0
Aug-12	5.2	0.0	3.5	0.3	0.0	1.0	0.0
Sep-12	4.1	0.0	2.8	0.2	0.0	0.8	0.0
Oct-12	2.5	1.0	1.7	0.1	0.0	0.5	0.0
Nov-12	0.0	5.1	1.2	0.3	0.1	0.3	1.0
Dec-12	0.0	4.9	0.8	0.9	1.9	1.5	0.5
Annual	31.2	20.8	24.6	10.4	3.9	7.8	1.9

Table 21. Monthly IDC Results for Rural Residential, 2012 (inches).

Month	Surface Layer Fluxes (inches)						
	AW	Pr	ET_{aw}	ET_{pr}	DP_{pr}	DP_{aw}	RO
Jan-12	0.0	2.4	0.5	0.6	0.0	0.0	0.2
Feb-12	0.0	1.0	0.6	1.1	0.0	0.0	0.0
Mar-12	0.0	3.7	0.5	1.3	0.0	0.0	0.3
Apr-12	0.0	2.6	0.5	2.8	0.1	0.0	0.3
May-12	4.8	0.0	2.0	1.8	0.8	1.3	0.0
Jun-12	4.0	0.0	1.7	0.6	0.1	1.1	0.0
Jul-12	2.6	0.0	1.1	0.3	0.2	0.7	0.0
Aug-12	2.7	0.0	1.1	0.3	0.1	0.8	0.0
Sep-12	3.5	0.0	1.5	0.3	0.1	1.0	0.0
Oct-12	2.6	1.0	1.1	0.2	0.1	0.7	0.3
Nov-12	0.0	5.1	1.1	0.3	0.2	0.5	1.7
Dec-12	0.0	4.9	0.8	0.9	1.5	1.2	1.2
Annual	20.1	20.8	12.4	10.4	3.2	7.4	4.0

Table 22. Monthly IDC Results for Vineyards and Orchards, 2012 (inches).

Month	Surface Layer Fluxes (inches)						
	AW	Pr	ET_{aw}	ET_{pr}	DP_{pr}	DP_{aw}	RO
Jan-12	0.0	2.4	0.9	0.5	0.0	0.0	0.1
Feb-12	0.0	1.0	1.0	0.9	0.0	0.0	0.0
Mar-12	1.9	3.7	1.4	0.9	0.6	0.3	0.2
Apr-12	1.6	2.6	1.2	1.5	0.7	0.2	0.2
May-12	3.4	0.0	2.5	2.3	0.2	0.4	0.0
Jun-12	5.4	0.0	3.9	1.6	0.1	0.7	0.0
Jul-12	6.1	0.0	4.5	0.9	0.0	0.8	0.0
Aug-12	6.2	0.0	4.5	0.5	0.0	0.8	0.0
Sep-12	5.4	0.0	3.9	0.3	0.0	0.7	0.0
Oct-12	3.2	1.0	2.4	0.2	0.0	0.4	0.0
Nov-12	0.0	5.1	1.2	0.3	0.1	0.4	0.7
Dec-12	0.0	4.9	0.8	0.9	1.6	1.4	0.3
Annual	33.1	20.8	28.2	10.6	3.4	6.2	1.5

Groundwater Pumping

Very little surface water is available for irrigation in the Study Area. Omochumne-Hartnell Water District (OHWD), which has a total service area of 30,000 acres along the Cosumnes River has purchased surface water from the Central Valley Project historically to provide a surface water supply to augment natural flows available to riparian diverters from the Cosumnes River and Dry Creek. In recent years, riparian diversions have decreased (SSCAWA 2014). Surface water supplies, when available to OHWD, are used for groundwater recharge in the Cosumnes River channel.

According to the DWR 2000 land use survey for Sacramento County and the land use analysis for 2011 and 2012 in this project, approximately 5,600 acres out of 62,000 irrigated acres based on the 2011 and 2012 land use analysis have access to surface water. The amount of surface water available to support irrigation is limited because of dry conditions in local creeks and rivers during the primary growing season.

Because of the extremely limited availability of surface water in the region for irrigation, annual groundwater pumping has been assumed equivalent to the estimated amount of applied water from the IDC model, with monthly values adjusted based on ET_{aw} patterns to better represent the full population of fields. Resulting monthly estimated pumping amounts are provided in Table 23 for 2011 and 2012.

Table 23. Monthly Groundwater Pumping Estimates for Irrigation, 2011 – 2012.

	Estimated Groundwater Pumping for Irrigation (acre-feet)	
Month	2011	2012
January	0	0
February	0	0
March	3,511	9,805
April	7,242	9,602
May	16,886	21,721
June	18,731	25,899
July	25,808	27,570
August	27,347	28,118
September	23,434	23,086
October	10,741	12,213
November	0	0
December	0	0
Totals	133,700	158,014

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