

Santa Clara Valley Water District Crop Irrigation Water Use Update

Prepared for the Santa Clara Valley Water District

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Introduction

Santa Clara Valley Water District (the District) has requested a review and update of crop water requirements used in the agricultural water use worksheet (Worksheet B). Growers with unmetered wells use the worksheet to estimate water use and the payment due to the District. Consequently, District revenues and water use by unmetered agricultural users depend critically on the accuracy of the crop water requirements used in the worksheet. The best available data have been reviewed and used to update the worksheet. The data represent the most accurate and current crop applied irrigation water (AW) requirements in the District.

1. Review and Update of Existing Worksheet

The agricultural industry in Santa Clara County has changed significantly over the last several decades. Contraction of irrigated acreage, most pronounced in North County, and a shift towards higher-value and more intensive crop production has been the primary trend. It follows that an update of crop irrigation water requirements must include a review of current crops produced in the county and common irrigation practices. To accomplish these tasks, several sources of publicly available data were used, as well as the expertise of Santa Clara County Farm Advisers to ensure that the updated data were representative of irrigation practices in the region.

All of the crops used in the previous worksheet are present in the updated worksheet, in addition to new crops being produced in the county. The Santa Clara County Annual Crop Reports and the Santa Clara County Pesticide Use Reports (PURs) were used to update the list of crops currently produced in Santa Clara County. The 2011 PUR lists the crops produced in Santa Clara County that used any type of pesticide. The PUR was cross-referenced with the 2011 Santa Clara County Annual Crop Report. If a crop was present in the crop report and PUR, it was included in the water use worksheet. If the crop was present in the PUR and not in the crop report, then the acreage was examined in the PUR to determine if this was a major crop grown in the county. Using this methodology, 65 crops and crop groups are included in the updated worksheet.

Due to similarities in cultural and water use practices and data limitations, some crops were grouped together in the updated worksheet. The crop groupings include:

- Asian Vegetables: Nappa cabbage, bok choy, gai choy, gai lon, kohlrabi.
- Lettuce: Head lettuce and leaf lettuce.
- Spinach and Salad Greens: Spinach, arugula, mustard, radicchio and swiss chard.

Crops with the same AW requirements include:

- Apple, cherry, orchard (mixed), pear (conventional and prickly), plum, and prune.
- Apricot, nectarine and peach.

- Artichoke, asparagus, beans (fresh), broccoli, Brussels sprouts, carrot, cauliflower, peas, and row crops (mixed).
- Barley, grain and wheat.
- Cabbage and lettuce.
- Cucumber, melon, pumpkin and squash.
- Eucalyptus, jojoba and kiwi.
- Garlic and onion.

Santa Clara County grows many crops in small acreages, in addition to specialty crops. Due to similarities in irrigation practices, these crops are grouped into “other” categories. The “other” crop AW requirements are in the worksheet and include the following groups:

- Other Field: flax, hops, grain sorghum, sudan grass, castor beans, hybrid sorghum/sudan, millet, sugar cane and miscellaneous field crops.
- Other Truck: Other miscellaneous small vegetables.
- Subtropical: grapefruit, lemons, oranges, dates, avocados, olives and miscellaneous subtropical fruit.

Table 1 summarizes the crop groups and data sources. The subsequent sections of this memorandum review the data, methods, and results.

Table 1. Santa Clara County Crop and Data Sources

Crop	Data Source
Alfalfa	California Department of Water Resources
Apple	Cal Poly Irrigation Training and Research Center
Apricot	Cal Poly Irrigation Training and Research Center
Artichoke	California Department of Water Resources
Asian Vegetables: Nappa cabbage, bok Choy, Gai Choy, Gai Lon, Kohlrabi	Cal Poly Irrigation Training and Research Center and personal communication with Michael Cahn, Farm Adviser
Asparagus	California Department of Water Resources
Barley	California Department of Water Resources
Beans (Bush)	California Department of Water Resources
Beans (Fresh)	California Department of Water Resources
Berries (Bushberries)	UCCE Cost & Return Study and personal communication with Mark Bolda, Farm Adviser
Broccoli	California Department of Water Resources
Brussels Sprouts	California Department of Water Resources
Cabbage	Cal Poly Irrigation Training and Research Center
Carrot	California Department of Water Resources
Cauliflower	California Department of Water Resources
Celery	UC ANR, and personal communication with Richard Smith and Michael Cahn, Farm Advisers
Cherry	Cal Poly Irrigation Training and Research Center
Christmas Tree	UCCE Cost & Return, Michigan State University, Kentucky State University
Corn (Field and Sweet)	California Department of Water Resources
Cucumber	Cal Poly Irrigation Training and Research Center
Eucalyptus	California Department of Water Resources
Flowers (Cut)	UC ANR, University of Arkansas, University of Maryland, University of New Hampshire, University of North Carolina, University of Massachusetts and personal communication with Michael Cahn, Farm Adviser
Flowers (Seed)	N/A.
Garlic	California Department of Water Resources
Grain	California Department of Water Resources
Herbs (Indoor)	UCCE, North Carolina State, ATTRA – National Sustainable Agriculture Information Service
Herbs (Outdoor)	UCCE, North Carolina State, ATTRA – National Sustainable Agriculture Information Service
Jojoba	California Department of Water Resources
Kiwi	California Department of Water Resources
Lettuce	Cal Poly Irrigation Training and Research Center
Marijuana	Mills (2011)
Melons	Cal Poly Irrigation Training and Research Center
Mushroom	Pennsylvania State University, Western Maryland Research & Education Center, University of Tehran and Campus Puebla Reports
Nectarines	Cal Poly Irrigation Training and Research Center
Onion, Dry	California Department of Water Resources

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Orchard (Mixed)	Cal Poly Irrigation Training and Research Center
Ornamental Plants	UC ANR, University of Arkansas, University of Maryland, University of New Hampshire, University of North Carolina, University of Massachusetts
Pasture (Hay)	California Department of Water Resources
Peach	Cal Poly Irrigation Training and Research Center
Pears	Cal Poly Irrigation Training and Research Center
Pears (Prickly)	Cal Poly Irrigation Training and Research Center
Peas	California Department of Water Resources
Peppers	Cal Poly Irrigation Training and Research Center
Persimmons	UC ANR, UC California Pesticide Impact Program
Plum	Cal Poly Irrigation Training and Research Center
Potato	California Department of Water Resources
Prune	Cal Poly Irrigation Training and Research Center
Pumpkin	Cal Poly Irrigation Training and Research Center
Rose Bushes	UC ANR, University of Arkansas, University of Maryland, University of New Hampshire, University of North Carolina, University of Massachusetts
Row Crops (Mixed)	California Department of Water Resources
Safflower	California Department of Water Resources
Sod	Personal communication with Michael Cahn, Farm Adviser
Spinach & Salad Greens	UC ANR, and personal communication with Aziz Baameur, Farm Adviser
Squash	Cal Poly Irrigation Training and Research Center
Strawberries	UCCE Cost & Return Study and personal communication with Mark Bolda, Farm Adviser
Sugar Beets	Cal Poly Irrigation Training and Research Center
Sunflower	Cal Poly Irrigation Training and Research Center
Tomato (Bush)	California Department of Water Resources
Tomato (Pole)	California Department of Water Resources
Vineyards (Grape)	California Department of Water Resources
Walnut	Cal Poly Irrigation Training and Research Center
Wheat	California Department of Water Resources
Other Field	California Department of Water Resources
Other Truck	California Department of Water Resources
Subtropical	California Department of Water Resources

Source: 2011 PUR, 2011 Santa Clara County Crop Report, DWR, ITRC, various publications and communication with Santa Clara County Farm Advisers.

2. California Department of Water Resources Data

The worksheet update used 2006—2010 California Department of Water Resources (DWR) Land and Water Use Data. DWR estimates crop AW requirements for statewide water planning regions known as Detailed Analysis Units (DAUs). Santa Clara County falls into two DAUs: San Jose and South Santa Clara Valley. The majority of agricultural production occurs in South County, the South Santa Clara Valley DAU. The most recent year (2010) of data for the South Santa Clara Valley DAU were used to update the worksheet.

The DWR Land and Water Use Data were used to update 29 of the 65 crops and crop groups: alfalfa, artichoke, asparagus, barley, broccoli, carrot, cauliflower, corn, beans (fresh market), dry beans¹, Brussels sprouts, eucalyptus, grain, jojoba, kiwi, wine grapes, onions and garlic, pasture, peas, potato², row crops (mixed), safflower³, tomatoes (fresh and processed), wheat, other field, other truck and other subtropical. Other sources were used for the remaining 36 crop groups including the Irrigation Training Research Center (ITRC), consultation with Santa Clara County Farm Advisers and other publications, further explained below.

3. Review and Compile Irrigation training Research Center Data

The ITRC at Cal Poly San Luis Obispo's 2003 report summarizes monthly and seasonal crop and soil evapotranspiration (ET) and AW requirements for 26 major crops in 18 production regions in California. The ITRC data is a more detailed crop list than the DWR Land and Water Use Data, and was used to supplement the data from DWR. All ITRC data used in the updated worksheet was based off of a year with normal rainfall, and therefore reflect standard average irrigation practices.

The ITRC report breaks down California into 18 major agricultural production areas. Santa Clara County falls under Region 8, the Inland San Francisco Bay Area, defined as “inland area near San Francisco with some marine influence.”

The ITRC AW data were applied to the following crops: apple, apricot, cabbage, cherry, cucumber, lettuce, melons, nectarines, orchard (mixed), peach, pears (conventional and prickly), peppers, plum, prune, pumpkin, squash, sugar beets, sunflower and walnuts.

4. Other Data Sources

Santa Clara County Farm Advisers were contacted to review crop AW estimates and, when available, provided additional data. Personal communication and studies provided by Farm

¹ No dry bean data were available for DAU regions in Santa Clara County. Instead, DAU 051 (Upper Valley) was used as a proxy region for AW rates.

² No potato data were available for DAU regions in Santa Clara County. Instead, DAU 076 (Cuyama Valley) was used as a proxy region for AW rates.

³ No safflower data were available for DAU regions in Santa Clara County. Instead, DAU 055 (Lockwood) was used as a proxy region for AW rates.

Advisers and other published reports were used to update AW requirements for Asian vegetables, bushberries, celery, herbs (indoor and outdoor), marijuana, mushrooms, sod, strawberries, spinach and salad greens, and Christmas tree production. Additional studies were reviewed to determine water use requirements for livestock, dairy, ranches, greenhouse and nursery production (including cut flowers, flowers for seed, ornamental plants and rose bushes). The following subsections summarize findings for these crops.

Asian Vegetables

Santa Clara County Farm Advisers are currently working to collect Asian and other small vegetable consumptive water use data. Although the data are unpublished, Advisers were able to share some preliminary findings (Cahn and Baameur, personal communication, 2014).

Data provided by Santa Clara County Farm Advisers were cross-referenced with DWR and ITRC data. Asian vegetables AW requirements aligned closely with AW requirements for spinach and salad greens, and onions and garlic. Cultural practices are generally similar between Asian vegetables, spinach and salad greens, and onions and garlic. Using the Farm Adviser, DWR and ITRC data, and knowledge of cultural practices in Santa Clara County, one acre-foot per acre for Asian vegetables was determined to be representative of average AW requirements.

Bushberries and Strawberries

Santa Clara County Farm Advisers recommended using University of California Cooperative Extension (UCCE) Crop Budgets for bushberry and strawberry AW requirements (Bolda, personal communication, 2014). Average bushberry and strawberry AW requirements in Santa Clara County range between 18 acre-inches and 36 acre-inches per acre. Farm Advisers indicated 24 acre-inches is representative of the average, as the majority of growers in the area will use this value for general rule-of-thumb AW requirements. The Cost and Return studies also provide the same water use requirements for bushberries (blackberries) and strawberries, which were updated in 2013 and 2011, respectively.

Celery

Celery water use requirements are generally different than other small vegetables, due to their shallow root system and susceptibility to blackheart, a result of calcium deficiency and dry soil. As a result of different water requirements, celery was not grouped together with other small vegetables. Two UCCE reports were used to estimate celery AW requirements (Daugovish, et al., 2008 and Koike, et al., 1996). The water use requirements in the reports varied between approximately 2.5 and 3.5 acre-feet per acre with sprinkler and furrow irrigation, and between 1.5 and 2.5 acre-feet per acre with drip irrigation systems.

Farm Advisers were consulted to discuss common celery irrigation practices in Santa Clara County (Cahn, personal communication, 2014). Based on the UCCE reports and Farm Adviser feedback, Santa Clara County celery requires an average of 1.75 acre-feet per acre.

Christmas Trees

There are limited data available for Santa Clara County Christmas tree production. A literature review found that the best available information for Christmas tree production and irrigation practices in California's Sierra Nevada Foothills (El Dorado, Placer and Nevada Counties), Michigan and Kentucky. Due to significant differences in cultural practices between these regions, Christmas tree AW requirements remain unchanged from AW requirements in the previous worksheet.

Herbs

Herb production literature from UCCE (Rogers, 1995), North Carolina State University (Gibson, et al., 2000), and ATTRA – National Sustainable Agriculture Information Service (Adams, 2005) were reviewed to determine herb AW requirements. A 2011 UCCE Cost and Return Study for outdoor peppermint production in the Sierra Nevada foothills indicated AW requirements of 3.5 acre-feet. This is slightly higher than the previous estimate, possibly due to geographic and cultural practice differences. Consequently, the AW requirements for herb production (indoor and outdoor) remain unchanged from the previous worksheet.

Marijuana

California is a major producer of marijuana in the United States. Marijuana can be grown outdoors, or with hydroponic (indoor) production. Outside of California's North Coast, marijuana is primarily produced indoors. A recent study examining cannabis energy use (Mills, 2011) indicated that indoor production annually requires approximately 40 gallons of water per day, per 240 square foot room. After scaling this up to per acre production, the AW requirement for marijuana produced indoors is 8.10 acre-feet per acre.

Mushrooms

Mushrooms ranked as the highest valued commodity in Santa Clara County in 2011 with gross revenue of over \$61.5 million. Mushroom production is characterized by composting and specific production phases. Compost is usually performed off-site and requires the most water during the mushroom production process. In contrast to standard crop production, water is recycled and reused during the compost process.

A literature review found several reports for mushroom production in other regions (Farashah, et al., 2013; Martinez-Carrera, et al., 2000; Royse, et al.; and Western Maryland Research & Education Center, 2003). These reports were used to estimate Santa Clara County mushroom farm water use.

Daniel Martinez-Carrera, et al. (2000) estimate AW requirements for oyster mushroom production in Mexico. These AW requirements were used as a proxy for mushroom AW requirements in Santa Clara County. AW requirements calculated using this method were below previous mushroom AW requirements.

Habib Reyhani Farashah, et al. (2013) examined energy efficiency of white mushroom production in the Alburz province of Iran. Their AW requirement estimate was also used as a proxy for AW requirements in Santa Clara County. AW requirements were also lower than previous mushroom AW requirements.

Farm Advisers were contacted to discuss mushroom AW requirements (De La Fuente, personal communication, 2014). Farm Advisers confirmed that much water is recycled during the mushroom production process. Mushroom AW requirements remain unchanged from those in the previous worksheet.

Persimmons

UCCE reports (Farrar, 1999 and LaRue, 1982) indicated that Persimmon AW requirements in the San Joaquin Valley range between 36 and 48 acre-inches, per acre. The AW requirements remain the same as the previous worksheet.

Sod

Santa Clara County Farm Advisers provided AW requirements for sod (turf grass) production in the county (Cahn, personal communication, 2014). The AW requirement for sod is 1.5 acre-feet per acre.

Spinach and Salad Greens

Spinach contributed \$2.4 million and salad greens contributed approximately \$5.4 million to agricultural output value in Santa Clara County in 2011. Spinach and salad greens (including arugula, mustard, radicchio, swiss chard) were grouped together for similarities in cultural practices. Spinach AW requirements are used as a proxy for salad green AW requirements.

UCCE reports were used to estimate spinach AW requirements (Koike, et al., 2011 and Takele, 2001). The report by Takele found AW requirements of approximately 11 acre-inches per acre. The report by Koike, et al. found AW requirements varied by crop type; (i) 4 to 8 acre-inches for clipped spinach, (ii) 6-12 acre-inches for fresh market bunch crop, and (iii) 18-24 acre-inches for processing spinach. These different AW estimates were confirmed with Santa Clara County Farm Advisers (Baameur, personal communication, 2014). Clipped and fresh market bunch crop are the predominant types of spinach grown in Santa Clara County and the Central Coast. Consequently, Santa Clara County spinach AW requirements are 11 acre-inches per acre.

Livestock, Dairy and Ranches

The most detailed and recent data for livestock water use were found in a report by the North Dakota State University Extension Service (2008). The National Range and Pasture Handbook (1997) was also used to determine water use requirements for dairy and beef cattle. Both sets of water use requirements were within range of the previous water use worksheet for livestock. As a result, livestock water use requirements were not changed from previous water use values.

The North Dakota State University report was also used to estimate water use requirements for sheep and pig ranches in Santa Clara County. Water use requirements for goats, rams and dry ewes are approximately equal to that of sheep, 2 gallons per day.

Average water use for a pig weighing between 100 and 200 pounds is 2 gallons per day. Most pigs that are sold to market fall between these weight ranges. Other pigs produced for intensive farming, as well as gilts (female pigs) will require more water, and smaller-sized pigs will require less.

Water consumption for equine is 9 gallons per day. These data were collected from a UC Davis Center for Equine Health report (University of California, Center for Equine Health, School of Veterinary Medicine, 2011) and a report written by the Placer-Nevada County Director and Farm Adviser (Ingram). Similar to sheep and pigs, the water use requirements will vary. The water use requirements for livestock, dairy and ranches do not reflect water used for grain or silage production to feed the animals.

Nursery

Bedding plants, woody ornamentals, and miscellaneous plants nursery production contributed \$86 million to the gross value of agriculture in Santa Clara County in 2011, over approximately 500 acres.

Nursery AW requirements vary with irrigation method, plant selection, plant spacing density, in addition to other factors. Nursery AW data are from several sources including University of California Department of Agriculture and Natural Resources (ANR) (Evans, et al., 2007), University of Arkansas Division of Agriculture (Robbins), University of Maryland (Majsztrik, et al., 2011 and Ristvey, 2004), University of New Hampshire Cooperative Extension (Neal, 2002), North Carolina Cooperative Extension (Bailey, et al., 1998; Bailey, et al., 1999 and; Bilderback, et al., 2012) and the University of Tennessee, Institute of Agriculture (Fulcher, et al. Part I and Part II).

The ANR (2007) publication provided monthly water use of ornamental crops in Half Moon Bay, for both greenhouse and outdoor crop production. The report estimated 2.79 acre-feet of water used for nursery ornamental crops. Other AW requirement estimates from the University of Tennessee and University of New Hampshire were also reviewed, but due to differences in irrigation and cultural practices, these data were not used.

A Farm Adviser, UCCE Researcher and chrysanthemum grower in the area were contacted to discuss AW requirements in nursery production (De La Fuente and Cheng, personal communication, 2014). AW requirements depend on irrigation system, plant spacing density, plant type, among other factors. Due to similar AW estimates from the ANR (2007) publication, AW requirements remain the same for rose bushes, ornamental plants and flowers for seed produced in nurseries.

Greenhouse

Greenhouses in Santa Clara County primarily support the cut flower and Chrysanthemum production in the County. A literature review identified six primary sources to determine AW requirements in greenhouse flower production including ANR (Evans, et al., 2007 and Schulbach, et al., 2009), University of Arkansas Division of Agriculture (Robbins), University of Maryland (Majsztzik, et al., 2011 and Ristvey, 2004), University of New Hampshire Cooperative Extension (Neal, 2002), North Carolina Cooperative Extension (Bailey, et al., 1998; Bailey, et al., 1999 and; Bilderback, et al., 2012) and University of Massachusetts (University of Massachusetts Amherst Extension Greenhouse Crops and Floriculture Program, 2009 and 2014).

Greenhouse AW requirements were calculated from the ANR Half Moon Bay (2007) report. Greenhouse ornamental crops annual water requirements are approximately 2.61 acre-feet per acre. The University of Arkansas and North Carolina State University data was used to calculate greenhouse AW requirements. Due to differences in irrigation and cultural practices, the Arkansas data was not used. Similar to nursery production, greenhouse AW requirements depend on the specific crop produced, irrigation system, plant spacing density, greenhouse climate, among other factors.

Santa Clara County Farm Advisers reviewed AW requirements in greenhouse, cut flower production. Based on Farm Adviser feedback in conjunction with the most current and regionally specific AW requirement data, cut flowers are determined to require 1.75 acre-feet, per acre (Cahn, personal communication, 2014).

5. Assumptions

Crop AW requirements depend on current cultural and irrigation practices.

Irrigation Systems

Crop irrigation water requirements vary by irrigation technology. New technology, such as subsurface drip and micro irrigation, can reduce applied water requirements by up to 50 percent when compared to surface irrigation. Santa Clara County Farm Advisers provided a list of the most commonly used irrigation methods in Santa Clara County (Baameur, personal communication, 2014). Table 2 summarizes common irrigation methods used in Santa Clara County. These methods are reflected in crop AW requirements in the updated worksheet.

The previous worksheet included a 50 percent cost savings for drip irrigation. The updated worksheet includes current irrigation methods, thus the drip irrigation savings is already reflected in the crop factors.

Table 2. Santa Clara County Irrigation Methods

Crop	Method	Crop	Method
Alfalfa	Sprinkler	Mushrooms	Drip/Micro
Apple	Drip/Micro	Nectarines	Drip/Micro
Apricots	Drip/Micro	Onions (Dry)	Sprinkler/Drip
Artichoke	Drip	Orchard (Mixed)	Drip/Micro
Asian Vegetables	Sprinkler	Pasture & Misc. Grasses	Sprinkler
Asparagus	Drip	Peaches	Drip/Micro
Barley	Sprinkler	Pear	Drip/Micro
Beans	Sprinkler/Drip	Pear (Prickly)	Drip/Micro
Broccoli	Sprinkler/Drip	Peas	Sprinkler/Drip
Brussels Sprouts	Drip	Peppers	Drip/Micro
Bushberries	Drip/Micro	Persimmon	Sprinkler
Cabbage	Sprinkler/Drip	Plum	Drip/Micro
Carrot	Sprinkler/Drip	Potato	Sprinkler/Drip
Cauliflower	Drip	Prune	Drip/Micro
Celery	Sprinkler/Drip	Pumpkin	Drip
Cherry	Drip/Micro	Rose Bushes	Sprinkler/Drip
Christmas Trees	Drip/Micro	Row Crops (Mixed)	Drip/Micro
Corn	Sprinkler/Drip	Safflower	Sprinkler
Cucumbers	Drip	Sod	Sprinkler
Eucalyptus	Sprinkler	Spinach & Salad Greens	Sprinkler/Drip
Flowers (Greenhouse, Cut)	Drip	Squash	Drip
Garlic	Sprinkler/Drip	Strawberries	Drip/Micro
Grain	Sprinkler	Sugar Beets	Sprinkler/Drip
Herbs (Indoor)	Drip	Sunflower	Sprinkler/Drip
Herbs (Outdoor)	Sprinkler/Drip	Tomatoes (Pole)	Drip
Jojoba	Sprinkler/Drip	Tomatoes (Bush)	Drip
Kiwi	Drip/Micro	Vineyard (Grapes)	Drip/Micro
Lettuce	Sprinkler/Drip	Walnuts	Sprinkler
Marijuana	Drip	Wheat	Sprinkler
Melons	Drip		

Source: Various reports and Aziz Baameur, Santa Clara County Farm Adviser

Note: Irrigation systems not included for flower (seed), herbs (indoor and outdoor), ornamental plants, rose bushes, other field, other truck or subtropical due to lack of irrigation data.

Single Cropping vs. Double Cropping

Common practice in vegetable and leafy green production is double-cropping, where two crops are grown back-to-back. Lettuce and cabbage are double-cropped and this is reflected in the applied water requirements. All other crops are single cropped.

6. Further Suggestions

Current worksheet mushroom AW requirements are based on a study conducted when mushroom production was not a large share of total agricultural value, and before improvements in technology had been incorporated into mushroom production. Updating these data would require assistance from the local mushroom Farm Adviser, as well as private producers.

Because of the non-standardized nature of nursery production, AW requirements are difficult to estimate. Research should be performed to determine AW requirements for different types of nursery products (e.g. ornamental flowers, woody ornamentals, plant bedding, etc.) and irrigation systems. Updating these data would require assistance from the local nursery Farm Adviser, as well as local nurseries.

Herb AW requirement data are limited. Literature generally cites optimal irrigation techniques, but lack quantitative AW data. To acquire these data would require assistance from local Farm Advisers, as well as local producers.

Farm Advisers indicated that the District is presently working with UCCE and private consultants to acquire more crop and region-specific water use data. Continuing these efforts will improve available water use data.

7. References

- Adam, Katherine L. "Herbs: Organic Greenhouse Production." 2005. ATTRA – National Sustainable Agriculture Information Service. Available at: <https://attra.ncat.org/attra-pub/summaries/summary.php?pub=53>.
- Aegerter, Brenna, Michael Cahn, Steven Koike, Richard Smith, Timothy Hartz and Trevor Suslow. "Asparagus Production in California." 2011. University of California, Division of Agriculture and Natural Resources. Available at: <http://anrcatalog.ucdavis.edu/pdf/7234.pdf>.
- Appleton, Bonnie L. and Deboarah B. Hill. "Kentucky Christmas Tree Production Workbook." 1986. Kentucky State University Cooperative Extension. Available at: www.uky.edu/Ag/CCD/introsheets/christmastrees.pdf.
- Baameur, Aziz. University of California Cooperative Extension Farm Adviser. Personal Communication, 2014.
- Bailey, Doug and Ted Bilderback. "Alkalinity Control for Irrigation Water Used in Nurseries and Greenhouses." 1998. North Carolina Cooperative Extension Service. Available at: <http://www.ces.ncsu.edu/hil/hil-558.html>.
- Bailey, Doug, Ted Bilderback, and Dick Bir. "Water Considerations for Container Production of Plants." 1999. North Carolina Cooperative Extension Service. Available at: <http://www.ces.ncsu.edu/hil/hil-557.html>.
- Bilderback, Ted, John Dole, and Ronald Sneed. "Water Supply and Water Quality for Nursery and Greenhouse Crops." 2012. North Carolina State University. Available at: <http://www.nurserycropscience.info/>.
- Bolda, Mark. Santa Cruz County Agricultural County Director and University of California Cooperative Extension Farm Adviser, Berries. Personal Communication, 2014.
- Cahn, Michael D. University of California Cooperative Extension Farm Adviser, Irrigation and Water Resources. Personal Communication, and unpublished data, 2014.
- California Department of Pesticide Regulation, Pesticide Use Reporting (PUR). 2011. Available at: http://www.cdpr.ca.gov/docs/pur/pur11rep/11_pur.htm.
- California Department of Water Resources (DWR), Agricultural Land & Water Use. 2006-2010. Available from DWR.
- Cal Poly Irrigation Training & Research Center (ITRC). "California Crop and Soil Evapotranspiration." 2003. Available at: <http://www.itrc.org/reports/californiacrop.htm>.

- Chen, Wen. Santa Clara County Agricultural Tech, University of California Cooperative Extension. Personal Communication, 2014.
- Cregg, Bert, Wendy Klooster, Amanda Taylor, R. Thomas Fernandez and Pascal Nzokou. "Container Production for Living Christmas Trees." Winter 2009. Michigan State University, Department of Horticulture, Department of Forestry. Available at: www.hrt.msu.edu/assets/PagePDFs/bert-cregg/PiP-MCTA-Journal.pdf.
- Daugovish, Oleg, Richard Smith, Michael Cahn, Hugh Smith, José Aguiar, Carlos Quiros, Marita Cantwell, Etaferahu Takele. "Celery Production in California." 2008. University of California, Department of Agricultural and Natural Resources. Available at: <http://www.anrcatalog.ucdavis.edu/pdf/7220.pdf>.
- De La Fuente, Maria. University of California Cooperative Extension Farm Adviser, Mushrooms and Nursery Production. Personal Communication, 2014.
- Evans, Richard Y., Linda Dodge, and Julie Newman. "Nutrient Management in Nursery and Floriculture." 2007. University of California, Department of Agricultural and Natural Resources. Available at: <http://anrcatalog.ucdavis.edu/Details.aspx?itemNo=8221>.
- Farrar, Kristen. "Crop Profile for Persimmons in California". 1999. University of California, California Pesticide Impact Assessment Program. Available at: <http://www.ipmcenters.org/cropprofiles/docs/capersimmons.pdf>.
- Farashah, Habib Reyhani, Seyed Ahmad Tabatabaeifar, Ali Rajabipour, Paria Sefeedpari. "Energy Efficiency Analysis of White Button Mushroom Producers in Alburz Province of Iran: A Data Envelopment Analysis Approach." 2013. Department of Agricultural Machinery Engineering, University of Tehran, Karaj, Iran. Available at: www.scirp.org/journal/PaperDownload.aspx?paperID=33002.
- Fulcher, Amy and Tom Fernandez. "Sustainable Nursery Irrigation Management Series, Part I. Water Use in Nursery Production." The University of Tennessee, Institute of Agriculture. Available at: <https://utextension.tennessee.edu/publications/Documents/W278.pdf>.
- Fulcher, Amy and Tom Fernandez. "Sustainable Nursery Irrigation Management Series, Part II. Strategies to Increase Nursery Crop Irrigation Efficiency." The University of Tennessee Institute of Agriculture. Available at: <https://utextension.tennessee.edu/publications/Documents/W279.pdf>.
- Gibson, James L., Brian E. Whipker, and Raymond Cloyd. "Success with Container Production of Twelve Herb Species." 2000. North Carolina State University. Available at: <http://www.ces.ncsu.edu/depts/hort/floriculture/hils/HIL509.pdf>.
- Higgins, Stephen F., Carmen T. Agouridis, and Amanda A. Gumbert. "Drinking Water Quality Guidelines for Cattle." 2008. University of Kentucky, College of Agriculture Cooperative Extension Service. Available at: www.ca.uky.edu/agc/pubs/id/id170/id170.pdf.

- Ingram, Roger. "How Much Water Do My Animals Need Each Day." University of California Department of Agricultural and Natural Resources. Available at: <http://www.ucanr.edu/sites/placernevadasmallfarms/files/90846.pdf>.
- Koike, Steven T., Michael Cahn, Marita Cantwell, Steve Fennimore, Michelle Lestrangle, Eric Natwick, Richard Smith and Etaferahu Takele. "Spinach Production in California." 2011. University of California, Department of Agricultural and Natural Resources. Available at: <http://www.anrcatalog.ucdavis.edu/pdf/7212.pdf>.
- Koike, Steven T., Kurt F. Schulback, and William E. Chaney. "Celery Production in California." 1996. University of California, Department of Agricultural and Natural Resources. Available at: <http://www.ucanr.edu/repository/a/?get=54029>.
- Koike, Steven T., Michael Cahn, Marita Cantwell, Steve Fennimore, Michelle Lestrangle, Eric Natwick, Richard F. Smith and Etaferahu Takele. "Cauliflower Production in California." 2009. University of California, Department of Agricultural and Natural Resources. Available at: <http://anrcatalog.ucdavis.edu/pdf/7219.pdf>.
- LaRue, James H., Karl W. Opitz, and James A. Beutel. "Growing Persimmons in California." 1982. University of California, Department of Agricultural and Natural Resources. Available at: http://www.ctahr.hawaii.edu/sustainag/extn_pub/fruitpubs/Growing%20Persimmons.pdf.
- Majsztzik, John C., Andrew G. Ristvey and John D. Lea-Cox. "Water and Nutrient Management in the Production of Container-Grown Ornamentals." 2011. University of Maryland, Department of Plant Science and Landscape Architecture. Available at: http://sensornet.umd.edu/publications/Majsztzik%20et%20al,%202011%20Hort.%20Reviews%2038_253-297.pdf.
- Martinez-Carrera, D., A. Aguilar, W. Martinez, M. Bonilla, P. Morales and M. Sobal. "Commercial Production and marketing of edible mushrooms and cultivated on coffee pulp in Mexico." 2000. College of Postgraduates in Agricultural Sciences, Campus Puebla, Mushroom Biotechnology. Available at: <http://www.hongoscomestibles-latinoamerica.com/P/P/19.pdf>.
- Mills, Evan. "Energy up in Smoke—The Carbon Footprint of Indoor Cannabis Production." 2011. Available at: <http://evan-mills.com/energy-associates/Indoor.html>.
- Neal, Catherine. "Efficient Water Use in Landscapes & Nurseries." 2002. University of New Hampshire Cooperative Extension. Available at: https://extension.unh.edu/resources/.../Resource000561_Rep583.pdf.
- North Dakota State University Extension Service. "Livestock and Water." June, 2008. Available at: <http://www.ag.ndsu.edu/publications/landing-pages/environment-natural-resources/livestock-and-water-as954>.

Nuñez, Joe, Tim Hartz, Trevor Suslow, Milt McGiffen and Eric T. Natwick. "Carrot Production in California." 2008. University of California, Department of Agricultural and Natural Resources. Available at: <http://anrcatalog.ucdavis.edu/pdf/7226.pdf>.

Owen, Jeffrey H., Richard A. McLaughlin and Janet Young. "Christmas Tree Production-Best Management Practices to Protect Water Quality and the Environment." 2000. Available at: www.soil.ncsu.edu/publications/assist/farmassist/treeFAS.pdf.

Pettygrove, Stuart, Tim Hartz, Blaine Hanson, Louise Jackson, Richard Smith, Tom Lockhart, and Steve Grattan. "Nutrient Management in Cool-Season Vegetables." 2003. University of California, Department of Agricultural and Natural Resources. Available at: <http://anrcatalog.ucdavis.edu/Details.aspx?itemNo=8098>.

Ristvey, Andrew George. "Water and Nutrient Dynamics in Container-Nursery Production Systems." 2004. PhD dissertation, University of Maryland. Available at: <http://www.psla.umd.edu/Faculty/lea-cox/Dissertations,%20Theses/A.G.%20Ristvey,%20PhD%20Dissertation%202004.pdf>.

Robbins, James. "Irrigation Water for Greenhouses and Nurseries". University of Arkansas Division of Agriculture. FSA 6061. Available at: http://www.uaex.edu/Other_Areas/publications/PDF/FSA-6061.pdf.

Rogers, Maureen A. "Herbs: A Small-Scale Agriculture Alternative." 1995. University of California Cooperative Extension. Available at: <http://sfp.ucdavis.edu/pubs/brochures/Herbs/>.

Royse, Daniel J. and Robert B. Beelman. "Six Steps to Mushroom Farming." Pennsylvania State University, College of Agricultural Sciences Agricultural Research and Cooperative Extension. Available at: <http://extension.psu.edu/plants/vegetable-fruit/mushrooms/publications/guides/SixSteps.pdf/view>.

Sanders, Douglas C. "Spinach." 2001. Department of Horticultural Science, College of Agriculture & Life Sciences, North Carolina State University. Available at: <http://www.ces.ncsu.edu/hil/hil-17.html>.

Schulbach, Kurt, Steve Tjosvold, and Danyal Kasapligil. "Improving irrigation systems conserves water in greenhouse-grown cut flowers." 1999. California Agriculture 53(2), 44-48. Available at: <http://ucanr.edu/repository/cao/landingpage.cfm?article=ca.v053n02p44&fulltext=yes>.

Smith, Richard. University of California Cooperative Extension Farm Adviser, Vegetable Crop Production and Weed Science. Personal Communication, 2014.

Smith, Richard, Aziz Baameur, Mohammad Bari, Michael Cahn, Deborah Giraud, Eric Natwick and Eta Takele. "Artichoke Production in California." 2008. University of California,

Department of Agricultural and Natural Resources. Available at:
<http://anrcatalog.ucdavis.edu/pdf/7221.pdf>.

Takele, Etaferahu. "Spinach Production: Sample Costs and Profitability Analysis." 2001.
University of California, Department of Agricultural and Natural Resources. Available at:
<http://www.ucanr.edu/repository/a/?a=54021>.

University of California, Center for Equine Health, School of Veterinary Medicine. "Minimum Standards of Horse Care in the State of California". December, 2011. Available at:
http://www.vetmed.ucdavis.edu/ceh/sp_standards.cfm.

University of California Cooperative Extension (UCCE). Cost of Production Studies. Various Crops and Dates. Department of Agricultural and Resource Economics. Davis, California. Available at: <http://coststudies.ucdavis.edu>.

University of Massachusetts Amherst Extension Greenhouse Crops and Floriculture Program. "Sizing the Greenhouse Water System." 2009. Available at:
<http://extension.umass.edu/floriculture/fact-sheets/sizing-greenhouse-water-system>.

University of Massachusetts Amherst Extension Greenhouse Crops and Floriculture Program. "Irrigation Systems." 2014. Available at: <http://extension.umass.edu/floriculture/greenhouse-best-management-practices-bmp-manual/irrigation-systems>.

United States Department of Agriculture National Agricultural Statistics Service, County Agricultural Commissioner's Data. Santa Clara County, Various Years. Available at:
http://www.nass.usda.gov/Statistics_by_State/California/Publications/AgComm/Detail/

United States Department of Agriculture Natural Resources Conservation Service, National Range and Pasture Handbook. Available at:
www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/landuse/rangepasture/?cid=stelprdb1043084.

Western Maryland Research & Education Center. "Shiitake Mushrooms Enterprise." 2003. Available at: <http://extension.umd.edu/wmrec>.