Applied Water Validation Study for the El Dorado County Agricultural Development Feasibility Assessment

SEPTEMBER 2025

PREPARED FOR
El Dorado Water Agency (EDWA)

PREPARED BY
Davids Engineering, Inc. (DE)

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List of Abbreviations

Listed below are the abbreviations used throughout the report. The abbreviations shown in ***italics*** reference key parameters from either the modeling or validation approaches.

2020 Report/EDWA, 2020 – El Dorado County Agricultural Development Feasibility Assessment
AE – Application efficiency
AF – Acre-feet
AN – Above-normal
AW – Applied Water
AW-IDC – AW calculated as ETAW-IDC divided by CUF-0.8
AW-OpenET – AW calculated as ETAW-OpenET divided by CUF-0.8
AW-OpenET-CUF-DU - AW calculated as ETAW-OpenET divided by CUF-DU
AW-WM – AW measured by water meters
BN – Below-normal
C – critical
CIMIS – California Irrigation Management Information Systems
CIT – Center for Irrigation Technology
CNRFC – California Nevada River Forecast Center
CUF – Consumptive use fraction
CUF-0.8 – CUF assumed to be 0.8
CUF-DU – CUF equal to measured median value from DU testing
CUF-IDC – CUF calculated as ETAW-IDC divided by AW-WM
CUF-OpenET – CUF calculated as ETAW-OpenET divided by AW-WM
D – Dry
DE – Davids Engineering
DP – Deep percolation
DU – Distribution uniformity
EDC Ag. Dept. – El Dorado County Agriculture Department
EDC or County - El Dorado County
EDFB – El Dorado Farm Bureau
EDWA or Agency - El Dorado Water Agency
EDWA, 2024 - 2024 Water Resources Development and Management Plan
EDWGGA – El Dorado Wine Grape Growers Association
EID - El Dorado Irrigation District
ET – Evapotranspiration
ET-IDC – ET extracted from the IDC root zone model
ET-OpenET – Remote sensing ET from OpenET
ETAW-IDC – ETAW extracted from the IDC root zone model
ETAW-OpenET – ETAW calculated as ET-OpenET minus ETPR-IDC
ETPR-IDC – ETPR from the IDC root zone model
ETAW – Evapotranspiration of applied water
ETPR – Evapotranspiration of precipitation
GDPUD – Georgetown Divide Public Utility District
GFCSD – Grizzly Flats Community Services District
IDC - Integrated Demand Calculator
IE – Irrigation efficiency
IMS – Irrigation Management Services
IN – Inches
IWFM – Integrated Water Flow Model
KM – kilometers
M – meters
NOAA – National Oceanic and Atmospheric Administration
NRCS – National Resource Conservation Service
P – Precipitation
P-NOAA – Precipitation obtained from NOAA
P-PRISM - Precipitation obtained from PRISM
PR – Precipitation
PRISM – Parameter-Elevation Regressions on Independent Slopes Model
RO – Runoff
SSURGO – Soil Survey Geographic Database
Study – Applied Water Validation Study for the El Dorado County Agricultural Development Feasibility Assessment
UC – University of California
UCCE – University of California Cooperative Extension
W – Wet
WM – Water Meters

Executive Summary

ES-1. Introduction

El Dorado Water Agency (EDWA or Agency) conducts long-term water resources planning to ensure that El Dorado County (EDC or County) has an adequate and reliable water supply to serve its needs now and into the future consistent with the County's adopted General Plan. In the Agency's 2024 Water Resources Development and Management Plan (EDWA, 2024), water supply-demand imbalance, unreliable groundwater resources, and vulnerability during droughts were identified as primary water resource-related challenges in the West Slope, where the County's existing agriculture is located.

As part of the planning efforts to understand long-term water supply needs to support planned agricultural growth, the Agency engaged Davids Engineering (DE) and ERA Economics to develop the *El Dorado County Agricultural Development Feasibility Assessment* (2020 Report) for the West Slope. Among other aspects of the assessment, DE estimated crop water demands and applied water requirements under various existing and possible future climate change conditions using the Integrated Water Flow Model (IWFM) Demand Calculator (IDC). At the time of the assessment, local applied water data were not available to validate the modeled estimates.

Recognizing the importance of model validation, the Agency tasked DE in late 2023 with conducting this *Applied Water Validation Study for the El Dorado County Agricultural Development Feasibility Assessment* (Study), which included an extensive field data collection program to measure applied water and collect data related to other IDC model parameters during the 2024 irrigation season. The primary objective of the Study was to evaluate the results of DE's modeling work from the 2020 Report to estimate applied water requirements for planned irrigated agriculture growth in EDC. Through the field data collection conducted in 2024, which had near-average precipitation, the Study provides relevant data that will inform long-term planning efforts.

ES-2. Methods

For the Study to be successful, it was necessary to identify active growers (and their respective irrigated lands) to participate in the Study and be included in the field review and data collection. Grower outreach and coordination were facilitated through project collaborators and direct outreach by DE staff. Growers and their associated lands were selected for inclusion in the Study based on a series of eligibility criteria, and irrigation units[1] were established to connect data from water meters with specific places of application for irrigation. In total, there were 28 irrigation units included in the Study covering a total of 255 irrigated acres. Over half were vineyards (54% by irrigation unit count, 63% by acreage), and the remainder were comprised of apples, Christmas trees, miscellaneous deciduous orchards, or

[1] An irrigation unit is defined as one or more fields receiving all the irrigation water measured through one or more water meters. The simplest scenario is where one water meter measures deliveries to one field; this meter-field combination would be an irrigation unit. However, in some cases multiple water meters are used to measure deliveries to multiple fields through a shared irrigation system (e.g., a water meter on the north and south sides of a larger property providing water into the same irrigation system used throughout the property). In these cases, the combination of all meters and all fields served by those meters would be an irrigation unit. The irrigation unit is the most discrete spatial scale at which results from the Study can be computed.

mixed cropping (primarily a mix of the four other crop types). This distribution is roughly consistent with the current distribution of irrigated acreage in the West Slope based on the 2020 Report.

Concurrent with the selection of growers and participating lands, the Study design was developed and data collection activities were outlined. The Study design initially required an understanding of how water moves through the irrigated lands of EDC. **Figure ES-1** is a schematic depicting the water flow paths of an irrigated field, distinguishing water by color between its two sources (precipitation: green boxes and arrows, and applied water: blue boxes and arrows). As the primary flow path identified for field review, applied water estimates are highlighted in the schematic along with an explanation of the modeling approach based on the 2020 Report and the validation approach in this Study.

Data collection included extraction of results from the IDC model developed in the 2020 Report, assembly of publicly available data and water utility data, and direct field data collection on participating lands. A variety of data were collected, aggregated, and evaluated to support the overall objective of validating applied water requirements. These included data on precipitation (P), evapotranspiration (ET), evapotranspiration of precipitation (ETPR), evapotranspiration of applied water (ETAW), the consumptive use fraction (CUF), distribution uniformity (DU), and applied water (AW). **Table ES-1** shows each of these along with a description of the modeling approach based on the 2020 Report and the validation approach and method used in the Study, along with a name for each parameter shown in *italics*. This approach allows for evaluation and then validation or potential refinement of each parameter. All these parameters affect applied water volumes.

The measurements of applied water through water meters allowed for direct comparison to applied water estimates from the 2020 Report (EDWA, 2020), which were calculated as the modeled evapotranspiration of applied water (ETAW) divided by an assumed consumptive use fraction (CUF) of 0.80[2]. The CUF is the ratio of ETAW to applied water (AW) with ETAW in the numerator and AW in the denominator (ASCE, 2016). For example, if 100 acre-feet (AF) of water were applied and 85 AF were consumed as ETAW, this would result in a CUF value of 0.85 (i.e., 85/100). For the CUF, a literature review of published values (or ranges of values) was also completed for comparison against the assumed 0.80 value from the 2020 Report and values determined from the Study. The IDC modeling period from the 2020 Report covered a 20-year period from 1998 through 2017, as described in the 2020 Report (EDWA, 2020). As part of this study, new precipitation and evapotranspiration (ET) inputs were prepared for the years 2018 through 2024 to extend the model period through 2024. This allowed extraction of 2024 results for ETAW from the IDC model for direct comparison to field measurement results.

DU testing was also completed as part of the field data collection program under the Study. DU is a metric describing how evenly water for irrigation is applied across an irrigated area. It is not equivalent to the CUF, a measure of how efficiently AW is consumed by crops as ETAW, but there is often a positive correlation between the two metrics: the higher the DU value is, the higher the CUF value tends to be as well. DU is expressed as a percentage; 100% represents a perfect DU, which is practically unattainable. DU was tested through a random sampling of irrigation emitter/sprinkler output across an irrigated area.

[2] The assumed average 80 percent across all crop, soil, slope and other variable West Slope conditions is relatively high compared to area-wide average efficiencies observed elsewhere in California, but is considered a reasonable expectation for planned irrigated agricultural growth in the West Slope (EDWA, 2020). Note that CUF in this report and irrigation efficiency from the 2020 Report describe the same value; see **Section 3.3.3** for more information.

The calculation of the CUF and of estimated AW requirements was also possible based on datasets collected as part of the Study that were not available during the development of the 2020 Report. For the CUF, these included calculating the CUF by: (1) dividing IDC results for ETAW by AW measured through water meters, (2) dividing OpenET results for ETAW by AW measured through water meters, and (3) direct comparison to DU results. For AW, these include calculating estimated AW requirements using the ETAW from OpenET data divided by the assumed CUF of 0.80 from the 2020 Report and divided by a CUF value based on the results of DU testing completed as part of the Study. The DU value represents the upper limit for the CUF (i.e., the CUF is likely slightly lower than the DU value)[3].

[3] There is typically a positive correlation between DU and CUF: in general, the higher the DU value is, the higher the CUF value will be as well. This is because the DU value usually sets the upper limit of the CUF value. A high DU accompanied by a high (although lower than DU) CUF represents high management proficiency (i.e., the irrigation system is being managed close to its potential). A high DU and low CUF indicates that the irrigation system components are well-maintained, but there is inadequate management in the timing and extent of irrigation relative to crop ET demands.

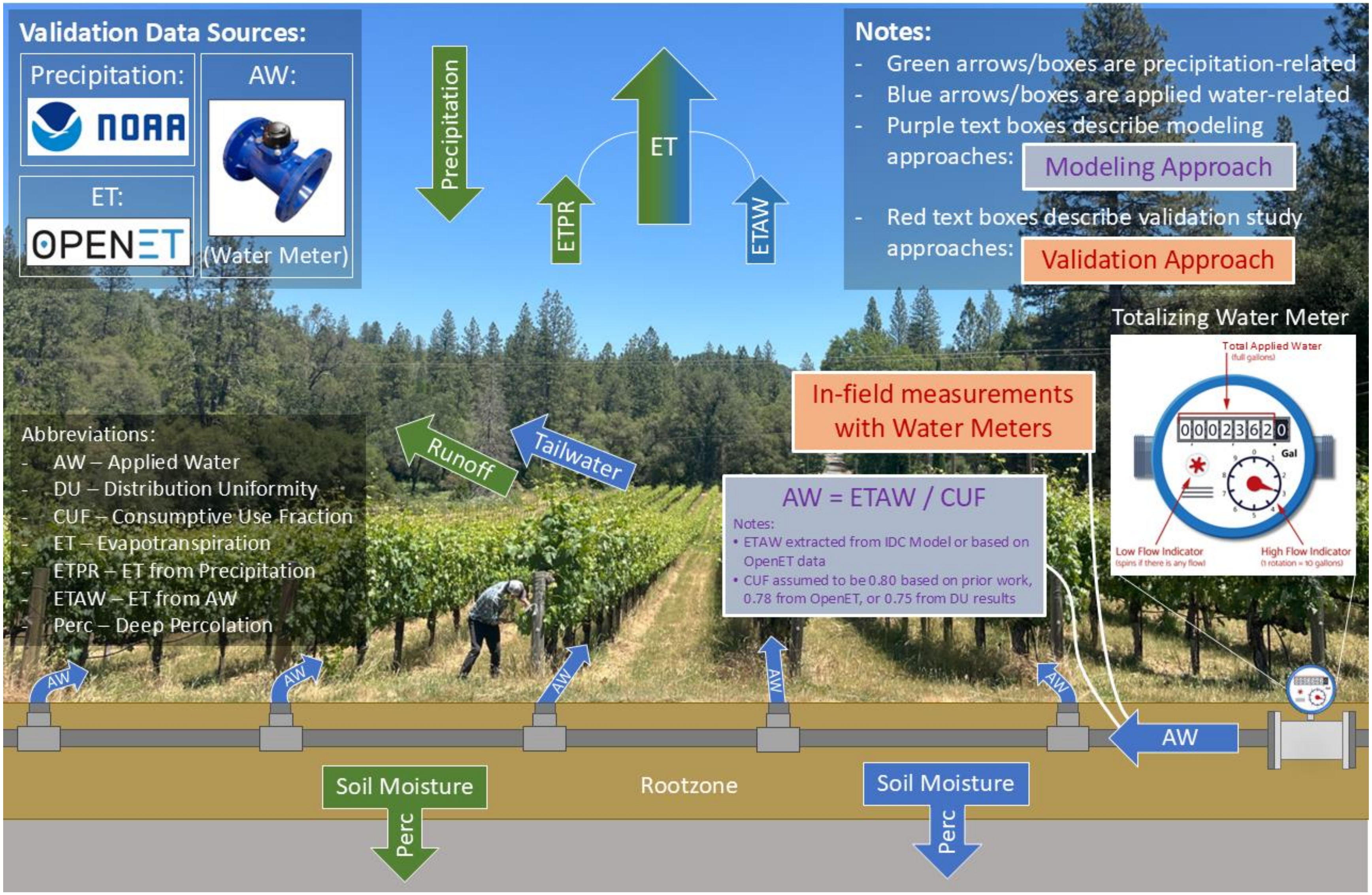

Figure ES-1. Overview of flow paths through an irrigated landscape (vineyard) in El Dorado County, distinguished by water source as either precipitation or applied water. Information is shown about the modeling approach and the validation approach for this Study for the review and comparison of applied water. It also includes information about validation data sources for other flow paths.

Table ES-1. Overview of flow paths and the consumptive use fraction, including description of data sources, assumptions, or calculations associated with the modeling approach and the current (2024) validation approach in this Study. A description of the validation method is also included. A unique term to label each parameter is also shown in italics in the table below (e.g., P-PRISM, P-NOAA, etc.); these labels will be used to refer to these flow paths throughout the report.

Flow Path or Consumptive Use Fraction (CUF)	Data Sources, Assumptions, or Calculations		Validation Method
	Modeling Approach[1]	Validation Approach[2]	
Precipitation (P)	PRISM data *(P-PRISM)*	NOAA Precipitation Gauges *(P-NOAA)*	Gridded PRISM precipitation data used as an input to the IDC model was compared to ground-based measurements of precipitation from precipitation gauges at four NOAA weather stations in EDC.
Evapotranspiration (ET)	CIMIS ETo multiplied by ETo Zone Factor multiplied by Kc (from 2017 METRIC analysis) *(ET-IDC)*	Remote Sensing data from OpenET *(ET-OpenET)*	IDC-modeled ET were calculated by multiplying CIMIS ETo values with ETo zone adjustment factors and 2017 METRIC crop coefficients. The model period was extended through 2024 and results were directly compared to average ET values within each irrigation unit available from OpenET, a satellite-based ET data source.
Evapotranspiration of Precipitation (ETPR)	ETPR extracted from IDC model *(ETPR-IDC)*	None *(ETPR-IDC)*	No validation was performed on the quantification of ETPR (as a portion of total ET) within the IDC model.
Evapotranspiration of Applied Water (ETAW)	ETAW extracted from IDC model *(ETAW-IDC)*	ET-OpenET minus ETPR-IDC *(ETAW-OpenET)*	The ETAW extracted from the IDC model was compared to ETAW calculated as the total ET from OpenET minus the ETPR value from the IDC model.
Consumptive Use Fraction (CUF)	Assumed to be 0.8 *(CUF-0.8)*	ETAW-IDC divided by AW-WM *(CUF-IDC)*	The 2020 assumption of 0.8 is compared to calculation of CUF based on modeled ETAW in IDC and AW measured through water meters.
		ETAW-OpenET divided by AW-WM *(CUF-OpenET)*	The 2020 assumption of 0.8 is compared to calculation of CUF based on ETAW from OpenET and AW measured through water meters.
		Measured Median DU *(CUF-DU)*	The 2020 assumption of 0.8 is compared to the DU measured through field testing as part of the Study.

<table>
<tr><th rowspan="2">Flow Path or Consumptive Use Fraction (CUF)</th><th colspan="2">Data Sources, Assumptions, or Calculations</th><th rowspan="2">Validation Method</th></tr>
<tr><th>Modeling Approach[1]</th><th>Validation Approach[2]</th></tr>
<tr><td rowspan="3">Applied Water (AW)</td><td>ETAW-IDC divided by CUF-0.8
(AW-IDC)</td><td rowspan="3">AW from in-field measurements of water meters
(AW-WM)</td><td>AW estimates based on IDC modeling were updated for 2024 and compared to measurements of actual AW from water meters installed on Study fields.</td></tr>
<tr><td>ETAW-OpenET divided by CUF-0.8
(AW-OpenET)</td><td>AW estimates based on OpenET data and an assumed CUF of 0.8 were compared to measurements of actual AW from water meters installed on Study fields.</td></tr>
<tr><td>ETAW-OpenET divided by CUF-DU
(AW-OpenET-CUF-DU)</td><td>AW estimates based on OpenET data and a CUF of 0.75 (median value from DU testing) were compared to measurements of actual AW from water meters installed on Study fields.</td></tr>
</table>

1. The data sources, assumptions, and calculations for the prior modeling approach are described in the 2020 Report, specifically Section 6 and Appendix D. The exception to this is applied water (AW), for which the modeling approach also uses data collected during the Study to calculate estimated AW requirements.
2. The validation approach utilizes data provided by this Study, except for Evapotranspiration of Precipitation (ETPR) which uses the IDC model from the 2020 Report.

ES-3. Results and Discussion

The quantitative results of the modeling approach based on the 2020 Report and validation approach in this Study are summarized below in **Table ES-2**, along with a calculated percent difference and validation summary. The precipitation analysis showed close agreement, with a less than 5% difference observed between P-PRISM and P-NOAA. Total ET showed a -13% difference relative to ET-OpenET from the Study, as ET-IDC from the 2020 Report was roughly 4 inches (IN) lower. ETPR was not evaluated as part of the Study and was assumed as effective precipitation for both the modeling and validation approaches. For ETAW, which represents a minority of total ET under both the modeling and validation approaches, ETWA-IDC had a -33% difference relative to ETAW-OpenET. Although there is uncertainty associated with results of both IDC modeling and OpenET, these differences observed in ET and ETAW suggest that the 2020 modeling approach underestimated both total ET and ETAW.

The CUF was an important parameter used to calculate estimated applied water requirements based on modeled ETAW as part of the 2020 Report. The CUF was assumed to be equal to 0.80 for all crops, irrigation methods, and other conditions and characteristics (although in reality CUF is variable dependent on these factors). It was acknowledged that this value was a conservative value potentially higher than many actual CUF values (as discussed below) but was considered a reasonable assumption for planned irrigated agricultural growth in El Dorado County. This assumed CUF value of 0.80 was compared to three different calculations of CUF under the current Study[4]:

1. CUF-IDC: This resulted in a value of <u>0.52</u>. As described below, this value is lower than expected. This is likely caused by underestimation of ETAW by the IDC model, although other factors may be influencing it as well.
2. CUF-OpenET: This resulted in a value of <u>0.78</u>. This value is within the range of expected values.
3. CUF-DU: The median value from DU testing resulted in a value of <u>0.75</u>. This value is also within the range of expected values. The DU represents an upper limit for the CUF.

Irrigation efficiency (IE) and application efficiency (AE)[5] are terms used to describe something similar to the CUF. Each has a slightly different definition and mathematical formulation, but they are often used interchangeably. A literature review revealed ranges of published values for IE and AE. Mean values for IE ranged from 0.63 for flood irrigation systems to 0.80 for pressurized sprinkler or drip irrigation systems (UNL, 2019). Mean values for the AE ranged from 0.72 for flood irrigation systems to 0.85 for pressurized drip or micro irrigation systems from one source (CIT, 2011), and from 0.66 to 0.73 and 0.74 for surface, sprinkler, and drip or micro, respectively, from another source (ASAE, 1990). Also, a historical evaluation of 16 irrigation systems in El Dorado County conducted in 1979-1980 showed DU values ranging from 0.46 to 0.85 with a median value of 0.73 (UCCE, 1981). The assumed CUF value of 0.80 from the 2020 Report is a conservative estimate near the upper end of the ranges presented, and the CUF-OpenET and CUF-DU values are slightly lower but still within the range of IE and AE reported, and they are slightly higher than the historical DU values measured in EDC in 1979-1980. One important factor influencing IE, AE, and CUF is topography. Elevation changes over an irrigated area, which are common for irrigated fields in El Dorado County and present across participating fields, often will reduce these values. For flood or surface irrigation "*nonuniform surface elevation is the main reason for nonuniform water distribution*" and for sprinkler irrigation systems, elevation changes "*can reduce the field DU [or AE] by 10 to 20%*" (ASCE, 2016). Other sources also acknowledge the impact of elevation

[4] The mathematical approach to calculate CUF-IDC, CUF-OpenET, and CUF-DU is shown in Table ES-1.

[5] Application efficiency (AE) is synonymous with distribution uniformity (DU).

changes on applied water for irrigation (UCCE, 1981; ASAE, 1983; ASAE, 1990). All else being equal, IE, AE, and CUF values for a foothill area such as EDC would be expected to be lower than in a relatively flat area such as the Central Valley due to topographic changes.

As another point of comparison, a similar dataset comparing applied water measured through flowmeters with ETAW from a variety of remote sensing products (including OpenET) to calculate CUF values was prepared in Madera County during 2023. The results showed CUF values ranging from 0.85 to 0.90 based on an aggregated data analysis and 0.77 to 0.80 based on a regression analysis for the same dataset (MCDWNR, 2024). The regression analysis values generally align with the upper end of range of mean values obtained for IE and AE from the literature review, while the aggregated data analysis values are higher. The higher CUF results observed in Madera County may be influenced by water scarcity, the practice of deficit irrigation, and careful management of available groundwater supplies under the Sustainable Groundwater Management Act (SGMA) and by more uniform soil types and the relatively flat topography on the San Joaquin Valley floor. The Study results for CUF-OpenET and CUF-DU (and assumption of 0.80 from the 2020 Report) were very similar to the regression analysis results, but below the range based on the aggregated data analysis.

As described above, DU testing was also part of the field data collection program for the Study. A total of 33 DU tests were completed; the results showed substantial variability from field to field, but the median value was equal to 75%. This value is slightly lower than the assumed CUF value of 0.80 from the 2020 Report, and the DU value represents a potential upper limit for the CUF, which would be expected to be slightly lower than DU values.

In summary, typically expected values for CUF range from around 0.60 to 0.90 for less efficient to more efficient applications of AW, respectively. The CUF-DU value was directly in the center of this range, while CUF-OpenET and the assumption of 0.80 from the 2020 Report were slightly above the average of this range.

Finally, the primary flow path for validation during the Study was applied water. As shown in **Table ES-2**, applied water was directly measured through water meters, with an average applied water depth across participating lands of 13.8 IN during the Study (AW-WM). The 9.0 IN of applied water estimated for participating lands from the IDC model for 2024 (AW-IDC) was 35% lower than measured values through water meters. Utilizing ETAW-OpenET and a CUF of 0.8 resulted in estimated applied water of 13.5 IN (AW-OpenET), which was 2% lower than measured values of applied water meters. Lastly, utilizing ETAW-OpenET and a CUF of 0.75 (the median results of DU testing) resulted in estimated applied water of 14.4 IN (AW-OpenET-CUF-DU), which was only 4% higher than measured values of applied water meters. These multiple calculations show the sensitivity of modeled results from the 2020 Report to changes in ET and CUF values, and the closer alignment of modeled applied water requirements utilizing OpenET data and DU results demonstrated refined estimates that more closely align estimated applied water requirements with the applied water measurements collected during the Study.

A cumulative line plot is shown in **Figure ES-2** depicting the four different AW values over 2024. From lowest to highest results for total AW, these are AW-IDC (9.0 IN), AW-OpenET (13.5 IN), AW-WM (13.8 IN), and AW-OpenET-CUF-DU (14.4 IN). The figure shows how these modeled and measured values accumulate over time. The slope and accumulation rate of all four flow paths showed some differences but were relatively similar during the winter and spring months between January and May, with all values being less than 2 IN. At the end of May, AW-OpenET and AW-OpenET-CUF-DU were slightly higher than AW-IDC, and AW-WM was the lowest. In May, the AW-IDC demands began increasing and these continued to accumulate at an increased rate relative to the start of the year throughout the remainder of 2024. However, the other three curves also began increasing in May, and they accumulated more quickly than AW-IDC from June through the end of September (the primary months of the irrigation season) and were roughly two-times larger by the end of September. The slopes of AW measured from water meters (AW-WM) and AW-OpenET were remarkably similar with the two lines nearly overlapping for much of this period. The slope of AW-OpenET-CUF-DU was slightly higher, and as a result, it remained the highest AW value from the moment it exceeded AW-IDC in April through the end of the year. During the month of October, near the end of the irrigation season, the accumulation rate (i.e. slope) between all four AW values was more similar than in the preceding and subsequent months. In the final two months of the year, AW-IDC continued to accumulate at a higher rate than the other three AW values, although it remained the lowest overall AW value. During these months, the accumulation rate of AW-WM measurements decreased as growers finished irrigation for the season. AW-OpenET and AW-OpenET-CUF-DU also leveled off and showed minimal accumulation over these final two months of the year. These results indicate that the 2020 AW estimates based on the IDC model underestimated ETAW and AW during the period from June through September, overestimated during November and December, and underestimated the total values accumulated during the Study period.

Table ES-2. Summary of average results from modeling and validation approaches, along with calculation of percent difference of modeling approach relative to validation approach. A validation summary is also included.

Parameter	Modeling Approach[1]	Model Results (IN or unitless for CUF)	Validation Approach[2]	Validation Results (IN or unitless for CUF)	% Difference	Validation Summary
P	P-PRISM	3.77	P-NOAA	3.64	4%	PRISM was approximately 4% greater than NOAA based on monthly comparison of four NOAA station and PRISM grid cells for historical available data.
ET	ET-IDC	24.3	ET-OpenET	27.9	-13%	ET-IDC was 13% lower than OpenET in 2024 (ET-IDC would need to be increased by 15% to match ET-OpenET).
ETPR	ETPR-IDC	17.1	ETPR-IDC	17.1	-	The same ETPR values were used for validation comparisons.
ETAW	ETAW-IDC	7.2	ETAW-OpenET	10.8	-33%	ETAW-IDC was 33% lower than OpenET in 2024 (ETAW-IDC would need to be increased by 50% to match ETAW-OpenET).
CUF	CUF-0.8	0.80	CUF-IDC	0.52	53%	The assumed CUF value of 0.8 was 53% higher than CUF calculated from ETAW-IDC and AW-WM.
		0.80	CUF-OpenET	0.78	3%	The assumed CUF value of 0.80 was 3% higher than CUF calculated using ETAW-OpenET and AW-WM.
		0.80	CUF-DU	0.75	7%	The assumed CUF value of 0.80 was 7% higher than the median value from field measurements of DU.
AW	AW-IDC	9.0	AW-WM	13.8	-35%	Modeled AW from IDC (AW-IDC) using the assumed CUF of 0.8 was 35% lower than water meter validation measurements of AW (AW-WM).
	AW-OpenET	13.5		13.8	-2%	Modeled AW from OpenET (AW-OpenET) using the assumed CUF of 0.8 was 2% lower than AW-WM measurements.

Parameter	Modeling Approach[1]	Model Results (IN or unitless for CUF)	Validation Approach[2]	Validation Results (IN or unitless for CUF)	% Difference	Validation Summary
	AW-OpenET-CUF-DU	14.4		13.8	4%	Modeled AW from OpenET using the CUF-DU of 0.75 (AW-OpenET-CUF-DU) was 4% greater than AW-WM measurements.

1. The data sources, assumptions, and calculations for the prior modeling approach are described in the 2020 Report, specifically Section 6 and Appendix D. The exception to this is applied water (AW), for which the modeling approach also uses data collected during the Study to calculate estimated AW requirements.
2. The validation approach utilizes data provided by this Study, except for Evapotranspiration of Precipitation (ETPR) which uses the IDC model from the 2020 Report.

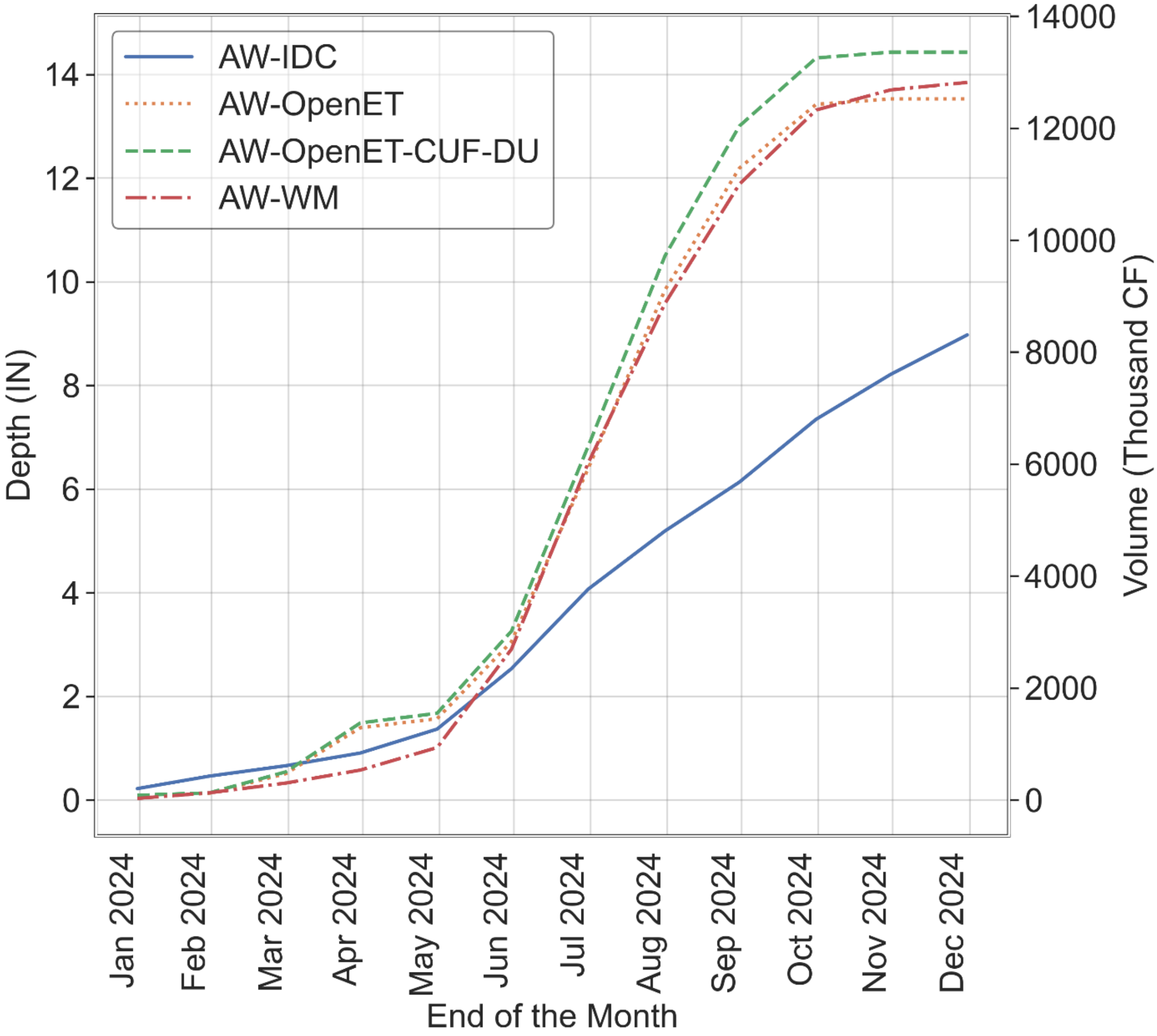

Figure ES-2. Cumulative line plot showing aggregated monthly results for applied water requirements based on the IDC model and a CUF of 0.8 (AW-IDC), applied water requirements based on OpenET data and a CUF of 0.8 (AW-OpenET), applied water requirements based on OpenET data and a CUF of 0.75, which was the median value from DU testing (AW-OpenET-CUF-DU), and measurements of applied water through water meters (AW-WM). A total of 28 irrigation units are represented in the data in this figure. The total volume presented on righthand side of the y-axis (in thousand cubic feet, Thousand CF) is divided by total irrigated area (i.e., 255 acres) to calculate the representative depth shown on the lefthand side of the y-axis (in inches, IN).

A total of 28 irrigation units representing 255 acres were included in the cumulative line plot shown in **Figure ES-2.** The total volume of applied water for all irrigation units is aggregated over time, as shown on the righthand side of the y-axis, and after dividing total volume by total irrigated area, it can also be expressed as a representative depth across the entire irrigated area, as shown on the lefthand side of the y-axis. This approach to aggregating the data gives greater weight to larger irrigation units (which have less relative uncertainty in their results compared to smaller irrigation units). It is also worth noting that vineyards most strongly impact these values. The overall participating lands in the Study were predominantly vineyards and vineyards had the largest average field size of all crop types included in the Study, which corresponds with the distribution of crop types in the West Slope.

The substantial difference observed between the 2020 modeling work (AW-IDC) and 2024 in-field measurements of applied water (AW-WM) illustrates the importance of completing field validations such as the one undertaken in this Study to compare in-field data against model assumptions. Other data collected during the Study highlighted other parameters and flow paths used to develop modeling estimates that could potentially be refined to improve alignment between modeled estimates and in-field measurements. In particular, the modeled estimates from the 2020 Report require adjustments to bring ET results into closer alignment with in-field measurements. ET estimates modeled in IDC for 2024 (ET-IDC and ETAW-IDC) were 13% and 33% lower, respectively, than OpenET results for participating lands in 2024. These results assume ETPR is equivalent for OpenET and IDC (ETPR-IDC). Applying the OpenET data to the modeled AW results brought them into close alignment with measured AW results (2% lower). Decreasing the CUF value from 0.80 to 0.75 based on the median value from DU (and continuing to use OpenET results) increased the modeled AW results by roughly 1 IN, causing them to be 4% higher than measured AW results.

ES-4. Conclusions

The overall objective of this Study was to validate the modeling results from the 2020 Report. Assembling independent data of actual measurements for review, refinement, or calibration of modeled results is a crucial step to validate modeling results by comparing how model inputs and assumptions align with actual measured values.

The data generated through this Study allowed for this comparison between AW values directly measured in the field and AW requirements estimated in the 2020 Report. They increased understanding of actual existing conditions for irrigated agriculture in El Dorado County, and they showed that modeled AW volumes from the 2020 Report were substantially lower than measured AW volumes. Additional data collected related to other flow paths and parameters provided more information about factors that may be influencing these AW estimates; in particular, the modeled ET estimates from the 2020 Report could potentially be increased and the assumed CUF value of 0.80 could potentially be decreased. Ultimately, the 2020 Report and this Study inform planning efforts for future applied water requirements in El Dorado County.

Table ES-3 shows how increasing the total ET estimated by the IDC model by 15% to match that observed in OpenET data, along with decreasing the CUF to 0.78 (CUF-OpenET, the value calculated using ETAW-OpenET and AW-WM) or 0.75 (CUF-DU, the median value from DU testing), will influence the estimated applied water requirements under future cropping and climate scenarios for three model runs from the 2020 Report. These adjusted values represent the low, middle, and high estimates of projected demands. These calculations assume that conditions during the 2024 Study are representative of long-term average conditions used to estimate applied water requirements in the 2020 Report (i.e., that conditions in 2024 for P, ET, and AW were representative of long-term average conditions between 1998 and 2017 and into the future). Based on historical data provided in this Study, the precipitation in

2024 was near average for the period from 2006 to 2024. All volumes in Table ES-3 below were rounded to the nearest thousand AF.

Table ES-3. Summary of changes to estimated applied water requirements due to adjustments to total ET and CUF based on Study results. ET-1.15 represents a 15% increase in total ET relative to the 2020 Report estimate, and CUF-0.XX represents various CUF values used to calculated AW requirements based on ETAW results. To the extent the 2024 Study period is representative of long-term average conditions, these values show how estimated applied water requirements would be impacted based on Study results.

Model Run	Cropping Scenario	Climate Scenario	Applied Water Requirements by Scenario (Volume in acre-feet, AF)			
			2020 Report Results	ET-1.15-CUF-0.80	ET-1.15-CUF-0.78	ET-1.15-CUF-0.75
8	Future	WW2040	64,000	96,000	98,000	102,000
4	Future	CT2040	68,000	102,000	105,000	109,000
7	Future	HD2055	78,000	117,000	120,000	125,000

Under Model Run 4 (the middle estimate), the 2020 Report showed estimated applied water requirements of 68,000 AF (EDWA, 2020). Increasing ET and/or decreasing the CUF results in increases to applied water requirements to between 102,000 AF and 109,000 AF (increases of 50% to 60% relative to the estimates from the 2020 Report). Although adjustments to total ET (increase of 15%) and CUF (decreases of 0.02 and 0.05) estimates are much smaller, any adjustments to ETAW can have a relatively large impact on total estimated applied water requirements, since the majority of total ET is met by ETPR and ETAW only represents a minority of total ET. As a result, the 15% increase in total ET represents a 50% increase in ETAW, relative to the estimate from the 2020 Report.

The Study results show that the 2020 Report's modeling work used conservative inputs and assumptions that led to conservatively low estimates of applied water demands. Actual measurements of applied water in 2024 as part of this Study were substantially higher than the estimates from the 2020 Report. The Study results provide increased understanding of existing conditions and a basis for potential refinement of the 2020 estimates of applied water requirements to inform future planning efforts.

1 Introduction

El Dorado Water Agency (EDWA or Agency) was created in 1959 through the El Dorado County Water Agency Act (Act) to ensure that El Dorado County (EDC or County) has an adequate water supply to serve its needs now and into the future. The Act recognizes the need for a countywide approach to water resource development and management that is consistent with the County's adopted General Plan, and the role of the Agency to fill that need. The geographic extent of the Agency's authority spans all of the County, including both the Tahoe Basin and the West Slope from the Sierra Nevada crest down to the foothills in the western portion of the County (West Slope) (see **Figure 1-1**).

Figure 1-1. Location of El Dorado County and west slope within El Dorado County (EDWA, 2024).

Recently, in 2024, the Agency revised its Water Resources Development and Management Plan (WRDMP) (EDWA, 2024) to evaluate all water resource-related challenges. The 2024 WRDMP is a comprehensive, integrated county-wide water plan with a long-term vision for water management for collective implementation among different agencies in EDC. In the 2024 WRDMP, water supply-demand imbalance, unreliable groundwater resources, and vulnerability during droughts were identified as water resource-related challenges in the West Slope. The supply-demand imbalance is expected to be intensified during drought conditions due to the lack of reliable groundwater resources.

As part of the planning efforts to ensure long-term water supply reliability to support planned agricultural growth, the Agency engaged Davids Engineering (DE) and ERA Economics in 2019 to conduct an agricultural development feasibility assessment for the West Slope to support its long-term agricultural water supply review. DE and ERA Economics developed an assessment summarized in **Section 1.3** and described in greater detail in the *El Dorado County Agricultural Development Feasibility Assessment* (2020 Report).

As part of the 2020 Report development, DE estimated crop water demands and applied water requirements under various existing and possible future cropping scenarios and climate change conditions using the Integrated Water Flow Model (IWFM) Demand Calculator (IDC)[6]. However, local applied water data were not available to validate the modeled estimates at the time of the assessment. Recognizing the importance of model validation, the Agency tasked DE in late 2023 with conducting this *Applied Water Validation Study for the El Dorado County Agricultural Development Feasibility Assessment* (Study). The Study included a field-based review of applied water estimates and other model parameters during the 2024 irrigation season, which had near-average precipitation. The primary objective of the Study was to validate the results of the 2020 Report to estimate applied water requirements for expansion of irrigated agriculture on the West Slope in EDC (Study Area). The Study outline, background, methods, and findings are presented in the following sections of this report.

1.1 Outline of Report Structure and Contents

This report includes the following sections and content:

1. The Introduction (**Section 1**) provides an overview of the Study location and its agricultural context; a review of the purpose, objectives, and results of the 2020 Report; and an outline of the purpose and objective of the current Study.
2. The Methods and Materials (**Section 2**) provides an overview of the methodologies and approaches used to achieve the Study objective. This includes approaches to identify participating growers and lands, an overview of Study design and flow paths and parameters to collect or assemble data for, and specific details and information related to the data collection, processing, analysis, and comparison to the 2020 Report findings for each individual flow path or parameter. These flow paths and parameters include precipitation (P), evapotranspiration (ET), the consumptive use fraction (CUF), and applied water (AW). The methodology for a historical analysis of P, ET, and AW based on available data is also described.
3. The Results and Discussion (**Section 3**) is structured with the same headings and subsections as the Methods and Materials. Under each heading, the results of the methodologies and approaches from Section 2 are presented and discussed in context of the 2020 Report and other considerations.
4. Conclusions (**Section 4**) includes conclusions identified during completion of the Study, stemming from Results and Discussion materials.
5. References (**Section 5**) includes a list of references cited throughout the report.

[6] IDC is a stand-alone root zone water budget modeling tool developed and maintained by the California Department of Water Resources (DWR). More information about it is available at: https://water.ca.gov/Library/Modeling-and-Analysis/Modeling-Platforms/Integrated-Water-Flow-Model-Demand-Calculator

6. Appendices (**Section 6**) provide additional information and detail regarding certain aspects of the Study that may be of interest but were not directly related to Study objective strongly enough to warrant inclusion in the main body of the report.

1.2 Overview of El Dorado County and its Agricultural Setting

El Dorado County has an important agricultural sector that supports local agritourism activities and generates income and tax revenue for the region. Apple Hill, generally located between Pollock Pines and the City of Placerville along the Highway 50 corridor, is a major agritourism hotspot in the fall. Farms across the County attract visitors from the greater Sacramento area for you-pick fruit and vegetables in the summer and choose-and-cut Christmas trees in the winter. Local vineyards produce grapes that are exported around the State and bottled at local wineries that bring more visitors into the County.

In 2023, irrigated agriculture in EDC generated over $43 million in gross value annually on approximately 5,500 acres (**Table 1-1)**, and the total value of agriculture is over $71 million when considering livestock and other non-irrigated agricultural land uses (EDAC, 2023). Crops produced also support significant economic activity in local industries including livestock, fruit processing, wineries, and agritourism. The value of County agriculture has been increasing over the last several decades in response to strong domestic and export market conditions, growing agritourism demand, and expansion of direct-to-consumer fresh produce markets.

Table 1-1 below depicts the gross value and irrigated acreage associated with select agricultural products (EDAC, 2023), along with irrigated acres within EDC based on a 2023 statewide coverage of irrigated lands available from DWR (DWR, 2023)[7]. Both coverages should be considered representative, but not exact, for EDC. The overall percent difference in total crop acreages between EDAC and DWR was only about 10%, which indicated general agreement between the datasets, despite the larger differences observed in crop-specific acreages. It is also worth noting that DWR acreages were likely a conservative estimate as they may be excluding some smaller irrigated areas that were not identified as part of development of the statewide coverage.

[7] These datasets from 2023 were the most recently available at the time of report preparation, and do not include any land use changes that may have occurred between 2023 and the time of the 2024 Study.

Table 1-1. Gross values and irrigated acres of agricultural products summarized from El Dorado and Alpine County 2023 Crop Report (EDAC, 2023), and total irrigated acres in EDC in 2023 from DWR (DWR, 2023), along with differences in acres.

Agricultural Products	Gross Value ($)[1]	EDAC Acres (AC)[1]	DWR Acres (AC)[2]	% Difference (Relative to EDAC, 2023)
Apples[3, 5]	$23,303,797	785	459	-42%
Livestock	$16,795,641	-	-	-
Wine Grapes[3]	$9,745,567	2,634	2,434	-8%
Hay and Pasture[4]	$8,363,199	1,570	806	-49%
Minor and Miscellaneous Crops[6]	$3,625,206	-	21	-
Nursery[7]	$2,840,126	48	142	196%
Stone Fruits[3, 8]	$1,831,102	251	319	27%
Pears[3]	$1,777,398	101	44	-57%
Berries[3]	$1,441,043	116	35	-70%
Christmas Trees[3, 7]	$1,348,980	-	142	-
Idle[9]	-	-	553	-
Total	**$71,072,059**	**5,505**	**4,956**	**-10%**
Total for irrigated crops only[10]	**$43,073,093**	**3,887**	**3,455**	**-11%**

1. Data from EDAC, 2023. Note that some agricultural products from the report are excluded from table above.
2. Data from DWR, 2023 (as described above).
3. Irrigated agricultural product (EDAC, 2023).
4. Partially irrigated agricultural product (EDAC, 2023).
5. Acreage from DWR, 2023 classified as miscellaneous deciduous (without a more detailed classification) was added to apples acreage.
6. Minor and misc. crops from DWR, 2023 included cucurbits, onions, garlic, and miscellaneous subtropical crops (e.g., citrus).
7. For nursery and Christmas trees, DWR classified them together as "flowers, nursery, & Christmas tree farms". The total acreage was divided evenly between these two EDAC categories.
8. Stone fruits included apricots, cherries, olives, peaches, plums, and walnuts from DWR, 2023.
9. Idle lands were identified and classified by DWR, but were not included in EDAC report.
10. Both coverages should be considered representative, but not exact, for EDC. The numbers from EDAC, 2023 are self-reported by growers, and the numbers from DWR, 2023 are a conservative estimate that may be excluding some smaller irrigated areas that were not identified during development of the statewide coverage.

Despite the social and economic importance of agriculture in the County, the water supply-demand imbalance and lack of reliable groundwater resources pose vulnerability to this important sector, particularly for irrigated crops. While the majority of the irrigated crop water demand is met by precipitation (EDWA, 2020), the remaining crop water demands need to be met by other water supplies to ensure agricultural productivity and sustainability. Therefore, the 2024 WRDMP recognizes that reliable surface water supplies are foundational to maintain and continue economic growth (EDWA, 2024).

Figure 1-2 shows the western portion of the West Slope where the County's existing agriculture is located (DWR, 2023); this portion of EDC where existing agriculture is located defines the Study Area**.** Agricultural fields and farms in El Dorado County tend to be much smaller than farms further west in the Central Valley, and although they are scattered across the lower elevations of the West Slope, there are areas with more focused and concentrated agricultural development. Many of these areas with concentrated agricultural development are designated as rural-agricultural planning zones. The public water purveyors on the West Slope are El Dorado Irrigation District (EID), Georgetown Divide Public Utility District (GDPUD), City of Placerville, and Grizzly Flats Community Services District (GFCSD). The remaining areas outside of these boundaries rely on small diameter wells or small water systems. In the West Slope, shallow groundwater wells draw water from fractured rock formations, which tend to have inconsistent and unreliable water storage characteristics.

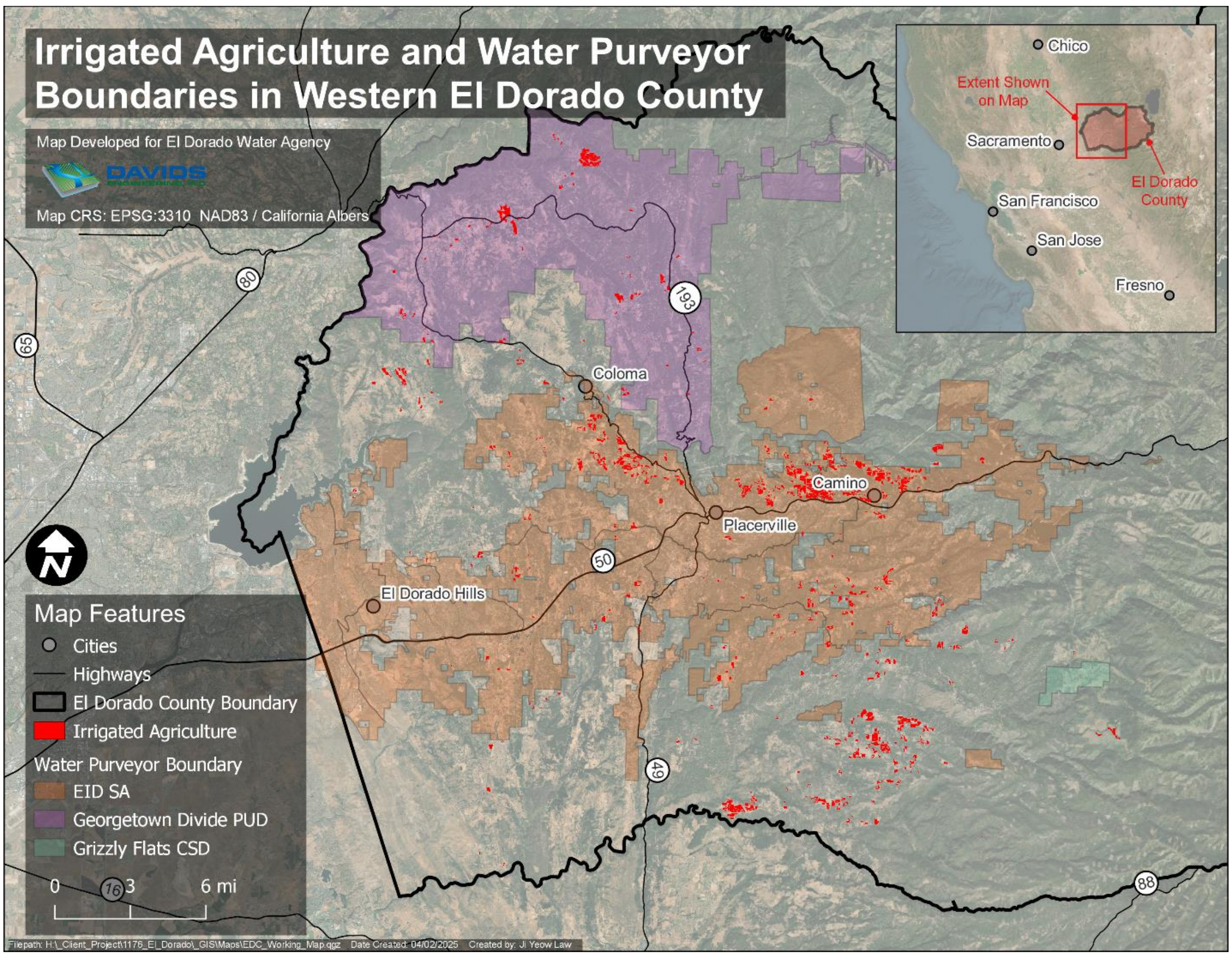

Figure 1-2. Coverage of existing irrigated agriculture (DWR, 2023) and water purveyor service areas in western El Dorado County.

As part of planning efforts to ensure long-term water supply reliability, a need to develop better understanding of water demands in EDC, especially in the rural-agricultural planning zones, was identified. This led to modeling work, as documented in the 2020 Report, and field validation work, as provided in this Study. Long-term water supply planning will help address existing water supply-demand imbalances, improve drought resiliency, and support planned agricultural growth.

1.3 Review of 2020 Report

1.3.1 Overview of 2020 Report and Objectives

Recognizing the importance of the rural-agricultural setting and economy to the County and to plan for both future agricultural development and potential impacts of climate change, the Agency worked with the County Agricultural Commissioner and local growers to assist in reviewing long-term agricultural water supply needs and evaluating the potential for expanding agricultural economic activities into areas identified in the County General Plan. In this effort, DE and ERA Economics were engaged to complete develop an agricultural feasibility development assessment for the West Slope. Among other objectives, this assessment aimed to improve the understanding of historical, existing, and future irrigated crop water demands and applied water requirements for the West Slope.

In 2020, DE and ERA Economics finalized the *El Dorado County Agricultural Development Feasibility Assessment* (EDWA, 2020). The report included baseline data and a framework to evaluate historical, current, and the potential range of future cropping and crop water demands for the West Slope. The project approach utilized an integrated engineering-economic analysis and included a geospatial analysis of land suitability (e.g., soil, slope, aspect), market (consumer demand) assessment and crop market potential for different West Slope crops, and future agricultural crop water demands under alternative climate conditions. The analysis ultimately estimated the potentially developable agricultural footprint in the County and its associated agricultural water demand. The Agency recognizes that realizing the planning and vision described in the County General Plan (EDC, 2024) requires many other investments by County, State, and federal agencies (e.g., California Department of Transportation), business interests, and other parties in the County and beyond. The Agency's scope focuses on water planning only.

As mentioned earlier in **Section 1**, the primary purpose of this report is to present and discuss the outcomes of the field evaluation of modeled results from the 2020 Report for potential model validation and refinement. Therefore, the subsequent review sections focus on summarizing the portion of the 2020 Report that estimated existing and future agricultural water demands. More details about the applied water modeling work along with other components of the integrated engineering-economic analysis are included in the 2020 Report (EDWA, 2020).

1.3.2 Summary of Modeled Applied Water Estimates

The IDC root zone water budget model was employed on a daily timestep for simulation of crop water demands. The flow paths included in the model are depicted in **Figure 1-3:** Inflows for the IDC root zone model were precipitation (PR[8]) and applied/irrigation water (AW), whereas the outflows were evapotranspiration (ET), runoff (RO), and deep percolation (DP). For model configuration, P and ET data were provided as inputs (along with other parameters), and the other water outflow paths were calculated by the model processes. Importantly, the IDC model tracks P and AW separately, allowing for computation of evapotranspiration of P (ETPR) and evapotranspiration of AW (ETAW) separately as well. Subsequently, AW demands were estimated by dividing ETAW by an irrigation efficiency value (or consumptive use fraction, CUF). Due to the lack of field data, the 2020 Report assumed a universal irrigation efficiency of 80% (i.e., CUF equal to 0.80) across the West Slope to calculate AW demands.

[88] Precipitation is abbreviated as PR in **Figure 1-3**, but is abbreviated as P throughout the remainder of this report.

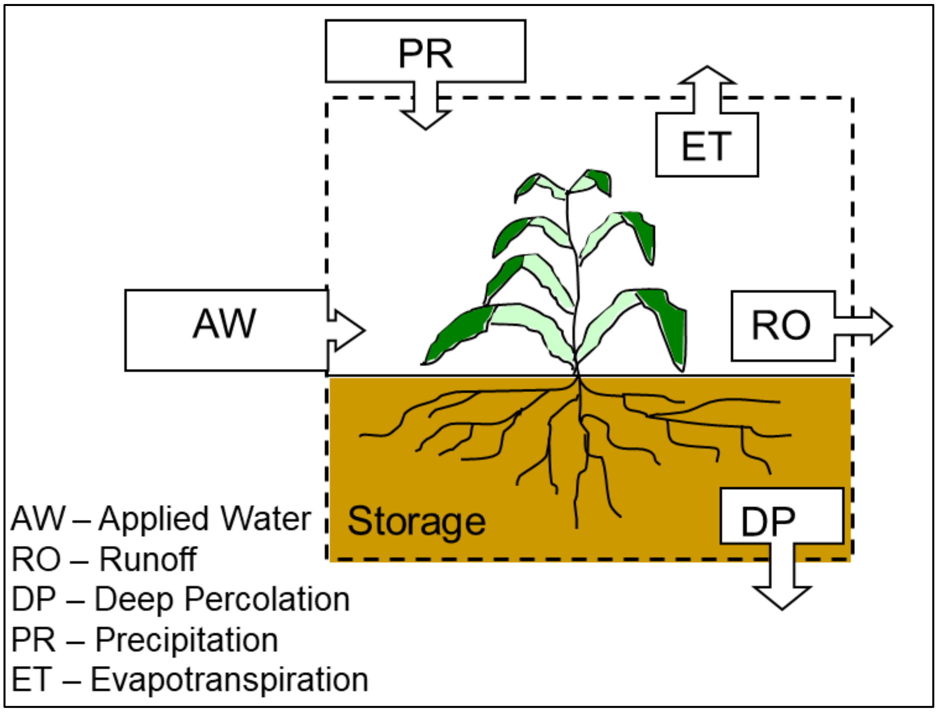

Figure 1-3. Conceptual representation of root zone water budget and inflow and outflow terms (EDWA, 2020).

Besides daily P and ET values, other parameters that impact water movement through the root zone were also included as model inputs. Briefly, these parameters included soil properties, rooting depth for each crop or land use class, and other model parameters for simulated land use classes and soil texture combinations, including soil moisture parameters and runoff curve numbers. More details on the model development and configuration are available in Appendix D of the 2020 Report.

The model was designed to simulate daily crop water consumption and applied water demands over a 20-year period (1998 through 2017) for various cropping patterns, crop evapotranspiration (ET) rates, and climate conditions. These scenarios are summarized as the nine model runs shown in **Table 1-2**.

Table 1-2. Parameters defining the nine IDC model runs (EDWA, 2020).

Run No.	Cropping[1]	Crop ET Rate[2]	Climate[3]	Run Code
1	Existing	Existing (average 2017 METRIC)	Historical	E50H
2	Future	Existing (average 2017 METRIC)	Historical	F50H
3	Future	Future (75th percentile 2017 METRIC)	Historical	F75H
4	Future	Future (75th percentile 2017 METRIC)	CT2040	CT2040
5	Future	Future (75th percentile 2017 METRIC)	CT2055	CT2055
6	Future	Future (75th percentile 2017 METRIC)	HD2040	HD2040
7	Future	Future (75th percentile 2017 METRIC)	HD2055	HD2055
8	Future	Future (75th percentile 2017 METRIC)	WW2055	WW2055
9	Future	Future (75th percentile 2017 METRIC)	WW2055	WW2055

[1] "Existing" refers to the existing cropping pattern on West Slope, whereas "future" included additional crops that were placed on all physically suitable and potentially economically viable fields.
[2] "Average" represents the typical average conditions, whereas "75th percentile" (i.e., values higher than "average") was used as a more conservative approach. The crop coefficients were estimated based on 2017 data using the remote sensing-based energy balance model named METRIC, as described in the 2020 Report.
[3] "Historical" refers to historical (1998-2017) climate conditions, whereas "CT", "HD" and "WW" represent central tendency, hotter drier, and warmer wetter climates, respectively, at two future years in 2040 and 2050. These six climate change scenarios were developed and are documented by the Bureau of Reclamation to support a variety of planning activities in the American River Basin.

Among the nine model runs, E50H is the closest representation of existing cropping and climate conditions in the West Slope, assuming negligible changes in conditions between the 1998-2017 modeling period and 2024 when this Study was conducted. Since the primary objective of this report was to validate the modeled estimates using field data collected during the 2024 Study, the following content will only focus on providing an overview of E50H model run results.

Summarized results for the E50H model run are presented in **Table 1-3**, representing area-weighted average results for the entire model period for five major existing irrigated crops (apples, Christmas trees, irrigated pasture, miscellaneous deciduous, and vineyards) on the West Slope. For each crop, two root zone inflows (P and AW) and four outflows (ETAW, ETPR[9], RO, and DP) are provided, with the sum of inflows and outflows equal to one another, assuming zero net change in storage over the course of each year, according to the principle of the conservation of mass. Over the 20-year model period (1998-2017) and five major crops, the area-weighted average of annual inflows and outflows was 52.0 IN. The average P and AW accounted for 74% and 26% of the annual inflows, respectively. Meanwhile, the average ETPR, ETAW, RO, and DP accounted for 35%, 21%, 21%, and 24% of the annual outflows, respectively.

The average annual crop ET demand was 28.8 IN, as represented by the sum of ETPR and ETAW. For the annual crop ET demand, approximately 63% and 37% of the demand was met by P and AW, respectively. This indicated that P is the primary water supply for irrigated crops on the West Slope, and the remaining the crop ET demand is met by AW. In comparing the five major crops, irrigated pasture had the highest AW of 25.9 IN; it was followed by Christmas trees (12.6 IN), miscellaneous deciduous (11.8 IN), apples (10.8 IN), and vineyards (6.3 IN).

[9] As described above, the IDC model tracks P and AW separately as they move through the root zone, allowing for computation of ETPR and ETAW separately as well.

Table 1-3. Estimated average annual inflows and outflows by major crop types for the 1998-2017 model period for the E50H model run.

Crop	Area	Inflows		Outflows			
	(AC)	P (IN)	AW (IN)	ETPR (IN)	ETAW (IN)	RO (IN)	DP (IN)
Apples	652	41.5	10.8	18.6	8.7	14.8	10.3
Christmas Trees	227	42.2	12.6	21.3	10.1	14.7	8.8
Irrigated Pasture	1,625	37.6	25.9	18.2	20.7	10.9	13.6
Misc. Deciduous	536	37.5	11.8	18.2	9.5	8.4	13.3
Vineyards	2,531	38.6	6.3	17.6	5.0	10.1	12.2
Total/Area Weighted Avg.	**5,572**	**38.7**	**13.3**	**18.1**	**10.7**	**10.9**	**12.4**
Area Weighted Avg. (as % of Total Inflows or Outflows)	-	**74%**	**26%**	**35%**	**21%**	**21%**	**24%**

As mentioned in the Introduction, the 2024 Study aims to compare the modeled estimates with field measurements and other independent datasets. To achieve this, the IDC model was updated with precipitation and ET data to extend the simulation period from 1998-2017 to 1998-2024. All other model assumptions and inputs remained the same as the previous E50H model run, as documented in the 2020 Report (EDWA, 2020).

Annual total crop ET demand remained mostly consistent throughout the 27-year model period (**Figure 1-4**) as ET demand was primarily affected by crop types and land uses. However, it is important to recognize that AW demands vary with time due to temporal variability in weather, particularly P. While the majority of annual ET demands were met by P (as indicated by ETPR), the ETAW was higher in years when the West Slope received lower P inflows, and subsequently, had lower ETPR.

As shown in **Figure 1-5**, the lowest AW demand was 7.8 IN during 1998 (second wettest year), and the highest AW demand was 17.3 IN during 2008 (fourth driest year, but preceded by the second driest year in 2007) for the modeled period included in the 2020 Report. In the more recent period, 2017 was recorded as the third wettest year, which resulted in a lower estimated ETAW. In contrast, 2020 was the third driest year, which likely contributed to higher ETAW in that year and the subsequent years of 2021 and 2022 (which remained dry). The highest ETAW and AW for the entire period from 1998 to 2024 were in 2021 with values of 15.2 IN and 19.0 IN, respectively.

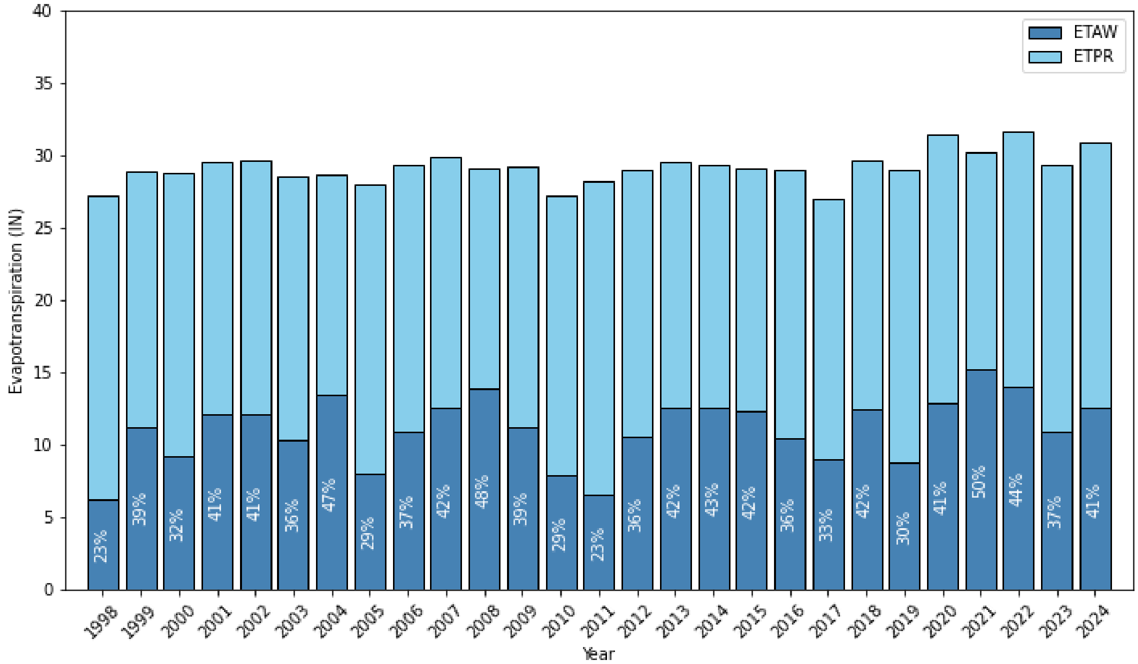

Figure 1-4. Annual depths (IN) of evapotranspiration of applied water (ETAW) and precipitation (ETPR) for all irrigated acreage on the West Slope from IDC model; ETAW is expressed as a percentage of total ET for each year.

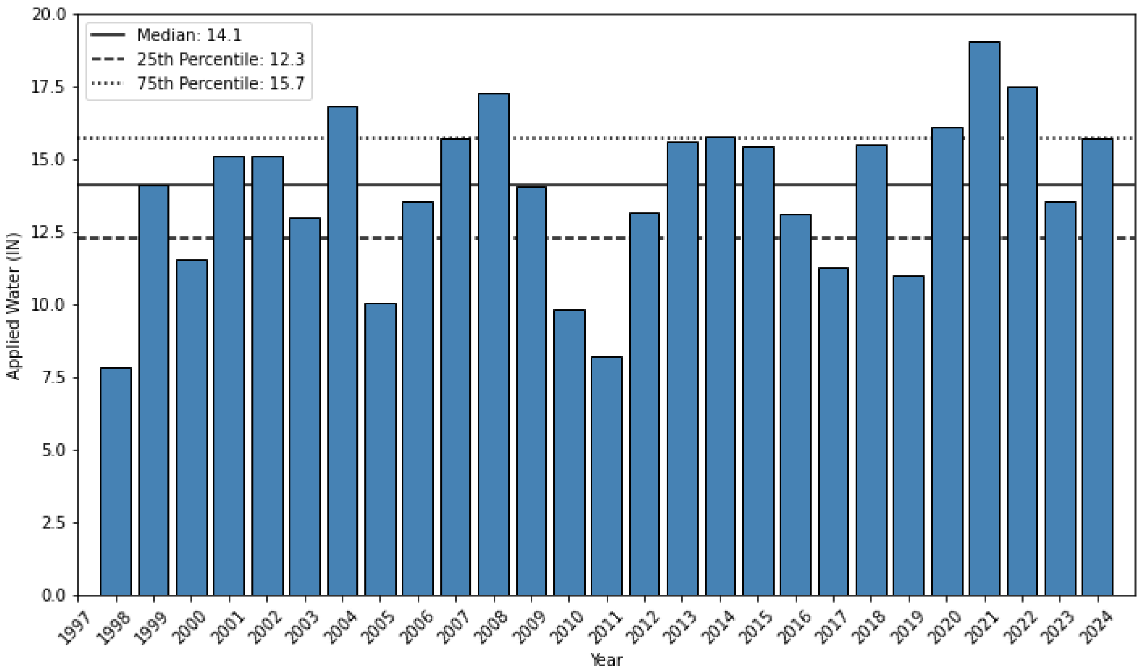

Figure 1-5. Annual depths (IN) of applied water (AW) for all irrigated acreages in West Slope from IDC model; the median, 25th percentile, and 75th percentile values are also shown as horizontal lines.

During 2024, the AW demand was 15.7 IN (**Table 1-4**), which was 2.4 IN higher than the 20-year average from the 2020 Report, despite receiving 1.3 IN more of precipitation than the 20-year average. The model also estimated higher ETAW, ETPR, and DP but a lower RO in 2024 compared to the 20-year average. This was likely due to a combination of factors, such as temperature and the timing of precipitation.

Table 1-4. Estimated annual inflows and outflows by major crop types for 2024 for the E50H model run.

Crop	Area (AC)	Inflows		Outflows			
		P (IN)	AW (IN)	ETPR (IN)	ETAW (IN)	RO (IN)	DP (IN)
Apples	652	42.5	13.1	18.8	10.5	13.4	10.7
Christmas Trees	227	43.1	14.8	21.7	11.8	12.9	7.8
Irrigated Pasture	1,625	39.3	29.7	18.4	23.8	9.6	11.6
Misc. Deciduous	536	38.4	14.3	18.3	11.5	6.4	13.6
Vineyards	2,531	39.8	7.8	17.9	6.2	8.4	12.9
Total/Area Weighted Avg.	**5,572**	**40.0**	**15.7**	**18.3**	**12.6**	**9.3**	**15.5**
Area Weighted Avg. (as % of Total Inflows or Outflows)	**-**	**72%**	**28%**	**33%**	**23%**	**17%**	**27%**

Elevation[10] varies substantially across EDC, and correspondingly, the elevation at which agriculture exists also varies. The variability with elevation changes in temperature and other weather parameters, along with differences in types of crops grown at different elevations, all impact the water demand (i.e., evapotranspiration) in respective zones. Besides water demand, the water supply (i.e., precipitation) also varies greatly with elevation. To account for these variabilities, six zones were delineated based on long-term evapotranspiration distribution patterns (the four furthest west are shown in **Figure 1-6**).

[10] Elevation in EDC varies from approximately 450 feet above mean sea level (AMSL) at its western edge to approximately 10,000 feet above MSL at crest of the Sierra Nevada at its eastern edge. Existing irrigated agriculture occurs primarily between 450 feet AMSL and about 4,000 feet AMSL within the Study Area.

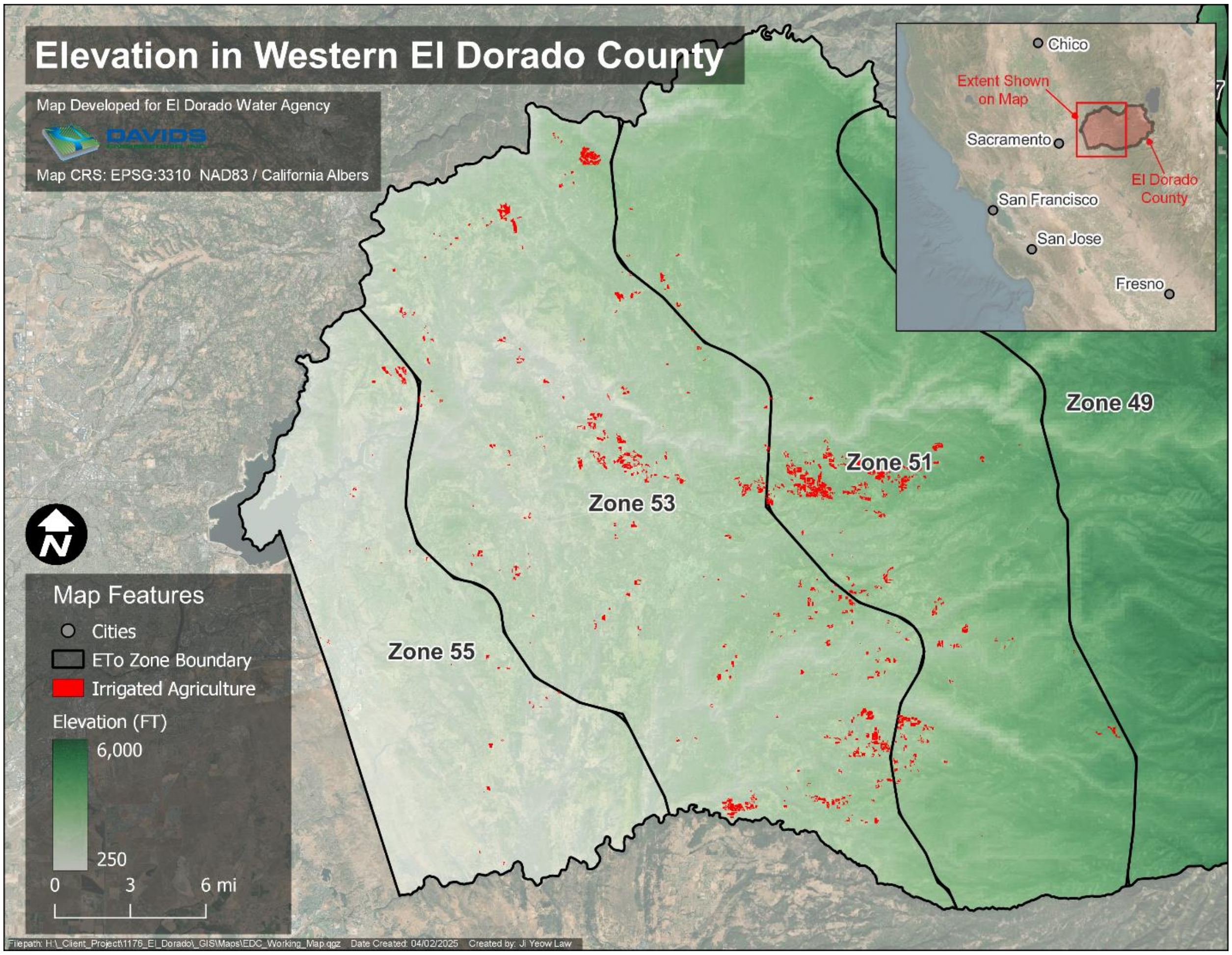

Figure 1-6. Four of six reference ET (Eto) zones delineated on the West Slope are depicted, along with elevation data and irrigated agriculture. The ETo zones were created to account for spatial variability in water supply and demand occurring in the Study Area, due primarily to variability in elevation and associated impacts.

1.3.3 Conclusions from the 2020 Report

In summary, the annual crop water accounting (simulated using the IDC model for the period of 1998-2017) estimated that an average of 13.3 IN of AW was needed per acre of irrigated field. Including the recently added model years of 2016-2024, the average AW requirements increased to 13.9 IN (5% increase over value from the 2020 Report). To account for extreme conditions, the highest AW demand was estimated to be 19.0 IN in 2021. Among all crop types, irrigated pasture was identified as the most water-intensive crop, whereas vineyards were estimated to have the lowest AW requirements.

While models are useful for simulation of various existing and possible future scenarios, there is a need to validate modeled estimates using field validation studies and on-the-ground data to verify model accuracy and evaluate the variability in model parameters (such as spatial weather patterns, soil types and properties, irrigation methods, and land management practices). Attempts were made during the development of the 2020 Report to verify the modeled “existing” E50H model run using locally available applied water data, but the attempts were not successful due data availability constraints. Recognizing the importance of validating modeled estimates using on-the-ground data, the 2024 Study was initiated, which is further detailed in the sections below.

1.4 Summary of Study Objectives

Following the context provided by review of EDC and the 2020 Report as described above, this section summarizes the Study objectives. The overall objective in the Study was to validate the results of the 2020 Report to estimate AW requirements for planned growth of irrigated agriculture in EDC. This included updating the model period through the present (but not applying any other model adjustments or modifications). The primary focus of the Study was on collecting and assembling additional data for comparison to modeled values for review, validation, and potential future refinement of modeling work from the 2020 Report.

The field-based data collection was dependent on active growers in EDC agreeing to participate and include their lands in the Study, and an early objective in the Study was collaborating with local ag-oriented entities and communicating with existing growers in order to identify Study participants and participating lands.

For participating lands, the objective of field data collection was to assemble a dataset for comparison to modeled values. This included assembly of publicly available data, water utility data, and in-field data collection for on-farm flow paths such as P, ET, and AW, and for other metrics and model parameters such as distribution uniformity (DU) testing and soils data collection. Once the data were assembled, collected, and processed, the final objective was to compare them against modeled values to validate or refine the 2020 Report findings to increase confidence in the modeled results.

2 Methods and Materials

2.1 Grower Recruitment and Coordination and Selection of Participating Lands

2.1.1 Coordination with Project Collaborators and Direct Grower Outreach

For the Study to be successful, it was necessary to connect and coordinate with active growers in EDC and have them participate for their respective irrigated lands to be included in the Study. Grower recruitment and coordination happened through multiple avenues, with the two most prominent being coordination with project collaborators and direct outreach to growers by DE staff. Methods for coordination and grower recruitment with collaborators are summarized in **Appendix A**. Direct grower outreach included coordination and outreach via email, phone calls, and in-person field visits. The agreement to participate in the Study was a voluntary, at-will decision made by growers on an individual basis after being contacted by collaborators or directly by DE staff.

2.1.2 Selection of Participating Lands

During grower recruitment and outreach, in addition to determining a grower's willingness to participate in the Study, their eligibility to participate in the Study was also evaluated. In order to be eligible, growers and their associated irrigated lands were required to agree to perform the following:

1. Provide access to lands for data collection
2. Share data collected as part of the Study in this final documentation
3. Continuously measure irrigation water deliveries over time
4. Associate applied water deliveries for irrigation with the final place of application
    a. Ideally, the measured water would all be applied for irrigation, but it was anticipated that some potential growers may have water meters that also measure water for other purposes (e.g., domestic, irrigation of landscaping, commercial, etc.). These other water demands would need to be able to be estimated for appropriate accounting in the Study.

The original scope of the Study anticipated finding roughly 30 growers who met all the criteria above within EDC. However, it was determined that very few of the growers had existing water meters already installed for measurement, with the exception of growers within El Dorado Irrigation District (EID), which meters its water deliveries and bills on a volumetric usage basis. Due to the lack of existing water meters, the scope of the Study was adapted to include the installation of water meters in suitable locations. If potential growers met all the requirements above except for the ability to continuously measure irrigation water deliveries over time, then DE staff coordinated with them to specify, purchase, and plan installations for water meters in locations where they would directly measure irrigation water deliveries to one or more agricultural fields. These meter installations expanded the number of growers and participating fields eligible for participation and allowed the Study to move forward during the 2024 irrigation season.

After the participating growers and associated irrigated lands were selected, their fields were delineated, meter locations were identified, and irrigation units were configured. An irrigation unit is defined as one or more fields receiving all the irrigation water measured through one or more water meters[11]. The irrigation unit is the most discrete spatial scale at which results from the Study can be computed.

Finally, it is worth noting that even if a grower and their associated irrigated lands were initially selected for inclusion in the Study, the data collected may not be able to be included due to data quality issues potentially caused by a variety of factors (e.g., an incomplete dataset, a malfunctioning water meter, etc.).

2.1.3 Ongoing Outreach during In-Field Data Collection, Data Analysis, and Documentation

Once the participating growers and their associated lands were selected and field data collection began, grower outreach continued as well. Over the course of the 2024 irrigation season and following the irrigation season as data were analyzed and documentation was prepared, outreach with growers was conducted (as necessary and beneficial) to coordinate on specific questions or data collection activities, to verify in-field conditions, or to share results for their individual lands included in the Study. These coordination activities continued through the development and finalization of Study documentation.

2.2 Overview of Study Design and Data Collection

Concurrent with selection of growers and participating lands, the Study design was developed and data collection activities were outlined. As described in the Introduction, the overall objective of the Study was to validate the applied water estimates previously developed through the 2020 Report. The Study design initially required an understanding of how water moves through the irrigated lands of EDC. **Figure 2-1** is a schematic depicting the water flow paths water of an irrigated field, distinguishing water by color between its two sources of precipitation (green boxes and arrows) and applied water, either surface water or groundwater (blue boxes and arrows). The key data types for the Study are also highlighted in **Figure 2-2**, along with information about data sources for each. Lastly, some information about additional supporting data collection to support Study objectives is shown.

In order to identify necessary data collection activities for the Study, the key flow paths (or model parameters) from the 2020 Report that would benefit from review, validation, and refinement need to be defined. The primary flow paths are precipitation (P), evapotranspiration (ET), and applied water (AW). Another key parameter (not a flow path) is the consumptive use fraction (CUF), or irrigation efficiency, as it is described in the 2020 Report. The CUF is a metric describing how much water is consumed by crops for growth relative to the total amount of water applied for irrigation, and it can be calculated by dividing the evapotranspiration of applied water (ETAW) by applied water (AW) (ASCE, 2016). Finally, another parameter included in the 2020 Report to be reviewed during field data collection was soils information, which was identified as an important factor influencing AW volumes by growers during grower coordination. Each of these flow paths and parameters will be described in more detail in subsequent sections. **Figure 2-2** shows each of these flow paths or parameters, how they were modeled or quantified as part of the 2020 Report, and how the Study collected and evaluated data in comparison to the 2020 Report for validation and potential refinement.

[11] The simplest irrigation unit scenario is where one water meter measures deliveries to one field; this meter-field combination would be an irrigation unit. However, in some cases multiple water meters are used to measure deliveries to multiple fields through a shared irrigation system (e.g., a water meter on the north and south sides of a larger property providing water into the same irrigation system used throughout the property). In these cases, the combination of all meters and all fields served by those meters would be an irrigation unit.

As described in the 2020 Report, the prior work was largely based on a series of IDC model runs. An overview of IDC model development and results is also provided in **Section 1.3**. As shown in **Table 2-1.** Overview of flow paths and the consumptive use fraction, including description of data sources, assumptions, or calculations associated with the modeling approach and the current (2024) validation approach under this Study. A description of the validation method is also included. A unique term describing each parameter is also shown in italics in the table below (e.g., P-PRISM, P-NOAA, etc.); these will be used to reference these through the report.

Flow Path or Consumptive Use Fraction (CUF)	Data Sources, Assumptions, or Calculations		Validation Method
	Modeling Approach[1]	Validation Approach[2]	
Precipitation (P)	PRISM data *(P-PRISM)*	NOAA Precipitation Gauges *(P-NOAA)*	Gridded PRISM precipitation data used as an input to the IDC model was compared to ground-based measurements of precipitation from precipitation gauges at four NOAA weather stations in EDC.
Evapotranspiration (ET)	CIMIS ETo multiplied by ETo Zone Factor multiplied by Kc (from 2017 METRIC analysis) *(ET-IDC)*	Remote Sensing data from OpenET *(ET-OpenET)*	IDC-modeled ET were calculated by multiplying CIMIS ETo values with ETo zone adjustment factors and 2017 METRIC crop coefficients. The model period was extended through 2024 and results were directly compared to average ET values within each irrigation unit available from OpenET, a satellite-based ET data source.
Evapotranspiration of Precipitation (ETPR)	ETPR extracted from IDC model *(ETPR-IDC)*	None *(ETPR-IDC)*	No validation was performed on the quantification of ETPR (as a portion of total ET) within the IDC model.
Evapotranspiration of Applied Water (ETAW)	ETAW extracted from IDC model *(ETAW-IDC)*	ET-OpenET minus ETPR-IDC *(ETAW-OpenET)*	The ETAW extracted from the IDC model was compared to ETAW calculated as the total ET from OpenET minus the ETPR value from the IDC model.
Consumptive Use Fraction (CUF)	Assumed to be 0.8 *(CUF-0.8)*	ETAW-IDC divided by AW-WM *(CUF-IDC)*	The 2020 assumption of 0.8 was compared to calculation of CUF based on modeled ETAW in IDC and AW measured through water meters.
		ETAW-OpenET divided by AW-WM *(CUF-OpenET)*	The 2020 assumption of 0.8 was compared to calculation of CUF based on ETAW from OpenET and AW measured through water meters.
		Measured Median DU *(CUF-DU)*	The 2020 assumption of 0.8 was compared to the DU measured through field testing as part of the Study.
Applied Water (AW)	ETAW-IDC divided by CUF-0.8 *(AW-IDC)*	AW from in-field measurements	AW estimates based on IDC modeling were updated for 2024 and compared to

Flow Path or Consumptive Use Fraction (CUF)	Data Sources, Assumptions, or Calculations		Validation Method
	Modeling Approach1	Validation Approach2	
		of water meters *(AW-WM)*	measurements of actual AW from water meters installed on Study fields.
	ETAW-OpenET divided by CUF-0.8 *(AW-OpenET)*		AW estimates based on OpenET data and an assumed CUF of 0.8 were compared to measurements of actual AW from water meters installed on Study fields.
	ETAW-OpenET divided by CUF-DU *(AW-OpenET-CUF-DU)*		AW estimates based on OpenET data and median CUF value from DU testing were compared to measurements of actual AW from water meters installed on Study fields.

1. The data sources, assumptions, and calculations for the prior modeling approach are described in the 2020 Report, specifically Section 6 and Appendix D. The exception to this is applied water (AW), for which the modeling approach also uses data collected during the Study to calculate estimated AW requirements.
2. The validation approach utilizes data provided by this Study, except for Evapotranspiration of Precipitation (ETPR) which uses the IDC model from the 2020 Report.

, the modeling approaches for each flow path and parameter are in reference to the 2020 Report, except for the applied water estimates that use data collected during the Study. The validation approaches are all in reference to work completed as part of this Study[12]. The furthest right column on validation method provides a brief description of how the validation approach will be compared against the modeling approach to review, validate, or potentially refine the modeling approach. **Figure 2-2** presents the same schematic presented above in **Figure 2-1**. However, for the key flow paths and parameters summarized in **Table 2-1**, this figure presents a visual summary of the modeling approach in the 2020 Report and validation approach in the current Study taken for each flow path and parameter. These flow paths and parameters are described in greater detail in subsequent sections.

[12] The exception to this is the evapotranspiration of precipitation (ETPR), for which the value extracted from the IDC model was also used for validation-related calculations.

Table 2-1. Overview of flow paths and the consumptive use fraction, including description of data sources, assumptions, or calculations associated with the modeling approach and the current (2024) validation approach under this Study. A description of the validation method is also included. A unique term describing each parameter is also shown in italics in the table below (e.g., P-PRISM, P-NOAA, etc.); these will be used to reference these through the report.

Flow Path or Consumptive Use Fraction (CUF)	Data Sources, Assumptions, or Calculations		Validation Method
	Modeling Approach[1]	Validation Approach[2]	
Precipitation (P)	PRISM data *(P-PRISM)*	NOAA Precipitation Gauges *(P-NOAA)*	Gridded PRISM precipitation data used as an input to the IDC model was compared to ground-based measurements of precipitation from precipitation gauges at four NOAA weather stations in EDC.
Evapotranspiration (ET)	CIMIS ETo multiplied by ETo Zone Factor multiplied by Kc (from 2017 METRIC analysis) *(ET-IDC)*	Remote Sensing data from OpenET *(ET-OpenET)*	IDC-modeled ET were calculated by multiplying CIMIS ETo values with ETo zone adjustment factors and 2017 METRIC crop coefficients. The model period was extended through 2024 and results were directly compared to average ET values within each irrigation unit available from OpenET, a satellite-based ET data source.
Evapotranspiration of Precipitation (ETPR)	ETPR extracted from IDC model *(ETPR-IDC)*	None *(ETPR-IDC)*	No validation was performed on the quantification of ETPR (as a portion of total ET) within the IDC model.
Evapotranspiration of Applied Water (ETAW)	ETAW extracted from IDC model *(ETAW-IDC)*	ET-OpenET minus ETPR-IDC *(ETAW-OpenET)*	The ETAW extracted from the IDC model was compared to ETAW calculated as the total ET from OpenET minus the ETPR value from the IDC model.
Consumptive Use Fraction (CUF)	Assumed to be 0.8 *(CUF-0.8)*	ETAW-IDC divided by AW-WM *(CUF-IDC)*	The 2020 assumption of 0.8 was compared to calculation of CUF based on modeled ETAW in IDC and AW measured through water meters.
		ETAW-OpenET divided by AW-WM *(CUF-OpenET)*	The 2020 assumption of 0.8 was compared to calculation of CUF based on ETAW from OpenET and AW measured through water meters.

Flow Path or Consumptive Use Fraction (CUF)	Data Sources, Assumptions, or Calculations		Validation Method
	Modeling Approach[1]	Validation Approach[2]	
		Measured Median DU *(CUF-DU)*	The 2020 assumption of 0.8 was compared to the DU measured through field testing as part of the Study.
Applied Water (AW)	ETAW-IDC divided by CUF-0.8 *(AW-IDC)*	AW from in-field measurements of water meters *(AW-WM)*	AW estimates based on IDC modeling were updated for 2024 and compared to measurements of actual AW from water meters installed on Study fields.
	ETAW-OpenET divided by CUF-0.8 *(AW-OpenET)*		AW estimates based on OpenET data and an assumed CUF of 0.8 were compared to measurements of actual AW from water meters installed on Study fields.
	ETAW-OpenET divided by CUF-DU *(AW-OpenET-CUF-DU)*		AW estimates based on OpenET data and median CUF value from DU testing were compared to measurements of actual AW from water meters installed on Study fields.

1. The data sources, assumptions, and calculations for the prior modeling approach are described in the 2020 Report, specifically Section 6 and Appendix D. The exception to this is applied water (AW), for which the modeling approach also uses data collected during the Study to calculate estimated AW requirements.
2. The validation approach utilizes data provided by this Study, except for Evapotranspiration of Precipitation (ETPR) which uses the IDC model from the 2020 Report.

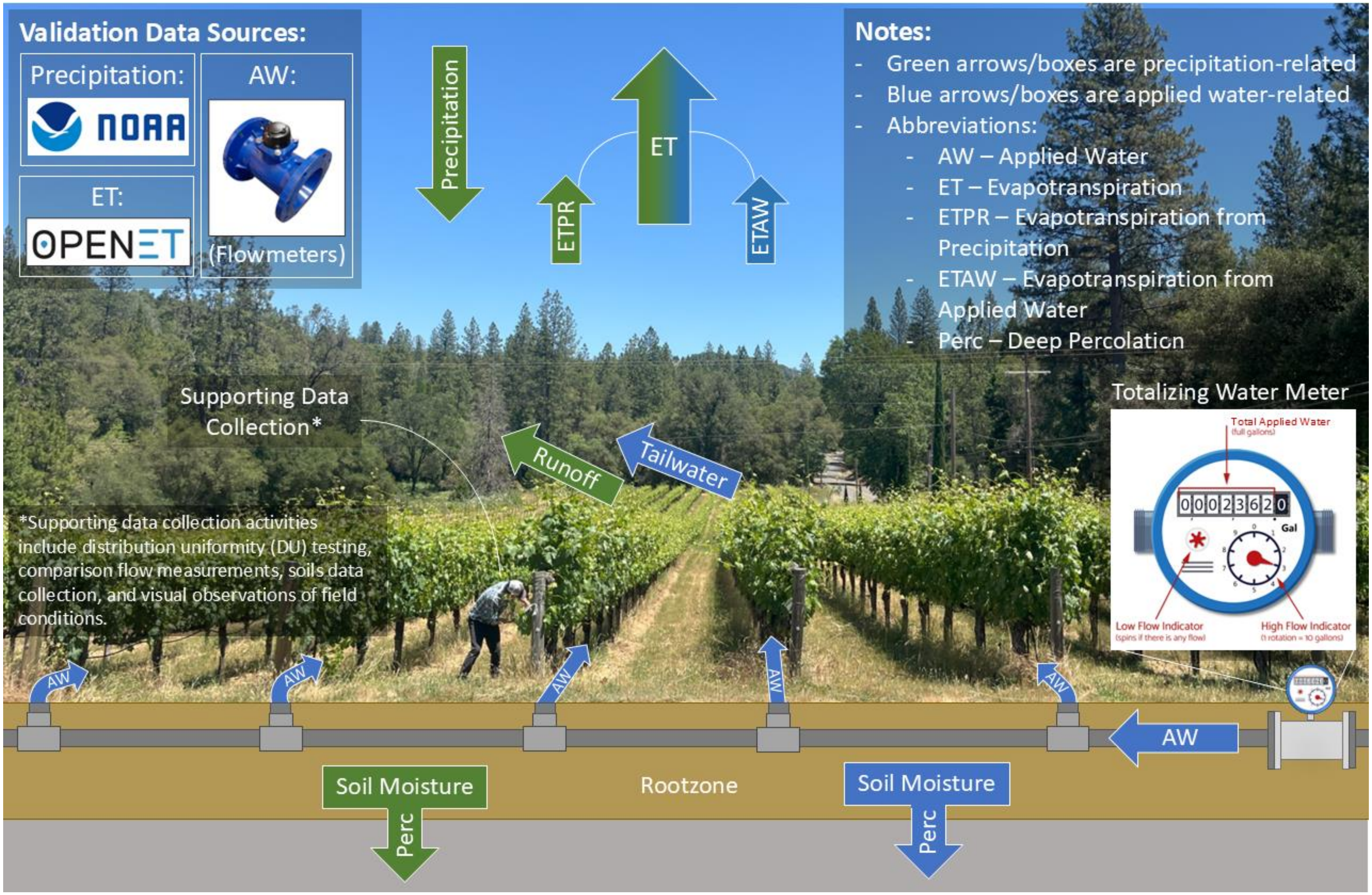

Figure 2-1. Overview of flow paths through an irrigated landscape (vineyard), distinguished by water source as either precipitation (green) or applied water (blue). This schematic also presents information about Study data sources to be used for validation and supporting data collection activities.

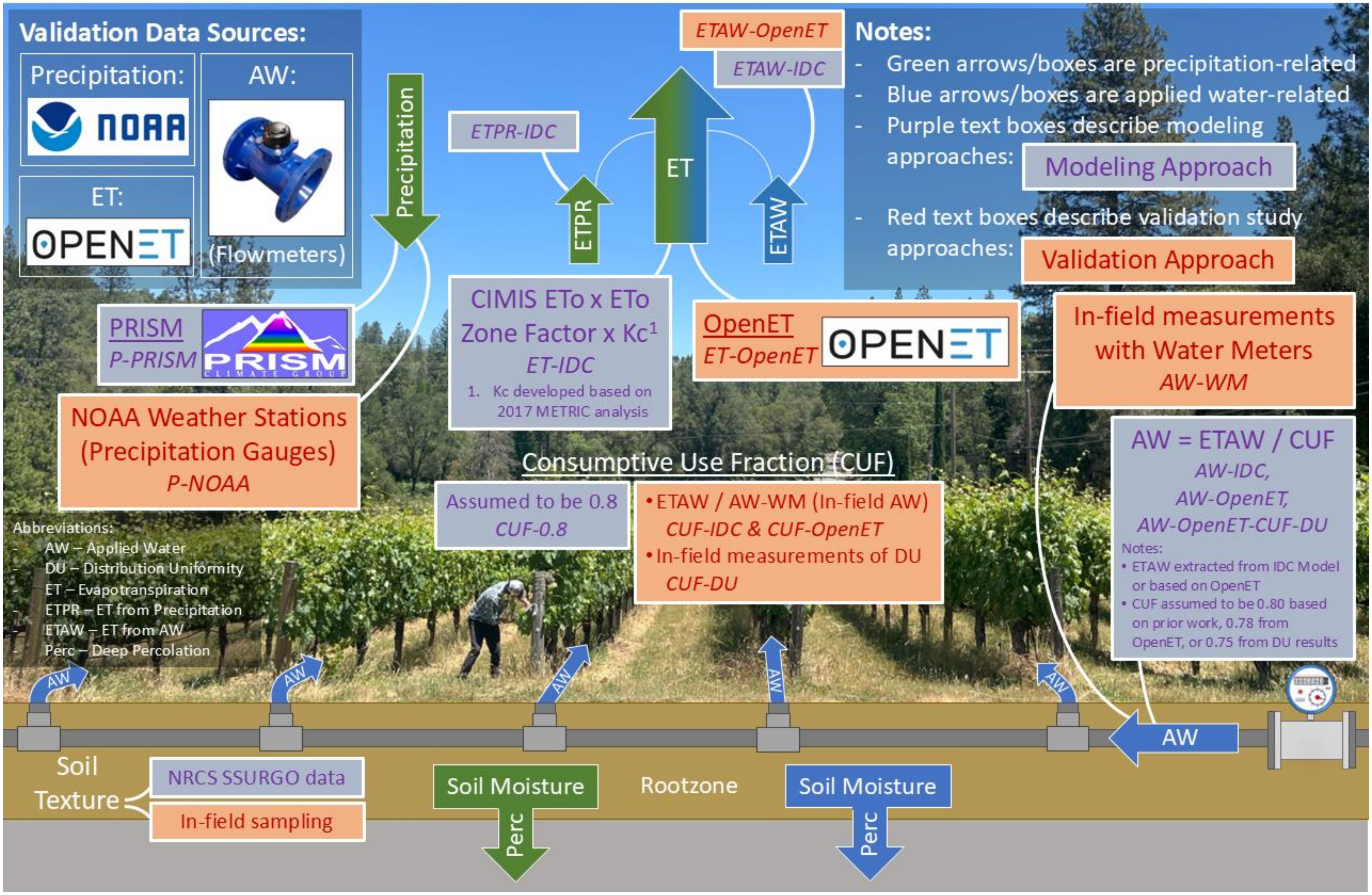

Figure 2-2. Overview of flow paths through an irrigated landscape (vineyard), distinguished by water source as either precipitation (green) or applied water (blue). The schematic also provides information about the modeling approach (purple text) taken in prior work and validation approach (red text) taken as part of this Study for the review, validation, and refinement of the 2020 estimates.

2.3 Data Collection, Processing, Analysis and Comparison to the 2020 Report

2.3.1 Precipitation

Precipitation is a natural inflow of water for an irrigated landscape that helps support crop ET demands. In California it can vary substantially from month-to-month and year-to-year, which directly impacts the volume of applied water for irrigation required for agriculture (i.e., in wet years, less applied water is required, and vice versa). Precipitation generally serves as the primary water source for agriculture in the Sierra Nevada foothills, such as in EDC, and meets the majority of the crop ET demands (see **Table 1-3**). Therefore, as part of the Study, it was crucial to evaluate the precipitation volumes and patterns in the Study Area in comparison to the 2020 Report to assess whether refinements are advisable.

2.3.1.1 P-PRISM

Precipitation was an important input into the IDC model utilized for the 2020 Report. The source for these input data was a gridded precipitation dataset obtained from the Parameter-elevation Regressions on Independent Slopes Model (PRISM), developed by the PRISM Climate Group at Oregon State University[13]. PRISM quantifies precipitation estimates, among other climate parameters, over space and time based on available weather station data and modeled spatial relationships with topography and other factors influencing weather and climate. PRISM data is available in raster coverages for the entirety of EDC on both a daily and monthly timestep from 1895 through the present, with a spatial resolution of either 4 kilometers (km) x 4 km or 800 meters (m) x 800 m. Due to the requirement of data covering the entirety of a model domain and the limited availability of point-based precipitation measurements from weather stations or rain gauges, PRISM data are often used for modeling applications such as IDC.

2.3.1.2 P-NOAA

To evaluate the PRISM data used in the 2020 Report, daily observed precipitation data were collected from precipitation stations maintained by the National Oceanic and Atmospheric Administration (NOAA) and available through their California Nevada River Forecast Center (CNRFC)[14]. Stations located on the West Slope of EDC, focusing on areas where there is existing irrigated agriculture, were identified, the data were reviewed, and all complete monthly records (i.e., months without any missing data and without any questionable data) were used for comparison to PRISM data. More information about the collection and evaluation of precipitation data is available in **Appendix B**. The resulting monthly precipitation values for the NOAA CNRFC stations were directly compared to the same monthly precipitation values from PRISM for the gridded cell in which the precipitation station is located.

2.3.1.3 ETPR-IDC

Although technically an ET output, the evapotranspiration of precipitation (ETPR) is directly related to total precipitation amounts. ETPR was quantified using IDC model results (ETPR-IDC), which separately track the movement of precipitation and applied water through the root zone and allow the separation of total ET into ETPR and the evapotranspiration of applied water (ETAW). Total ET is equal to the sum of ETPR and ETAW, and the division of total ET into ETPR and ETAW was not evaluated as part of the Study. ETPR-IDC values were used to calculate both ETAW-IDC and ETAW-OpenET, as described below.

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[13] More information about PRISM (including data access) is available at: https://prism.oregonstate.edu
[14] More information about NOAA CNRFC (including data access) is available at: https://www.cnrfc.noaa.gov/rainfall_data.php

2.3.2 Evapotranspiration (ET)

Evapotranspiration (ET), or consumptive use, is a critical water flow for irrigated agriculture and is important to quantify for a variety of water management and planning applications. In this context, consumptive water use is defined as "*the part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment*" (ASCE, 2016). It is the water consumed by crops to enable them to grow and mature (i.e., produce biomass), and it is typically the largest outflow of water from an irrigated landscape in semiarid environments. ET was quantified, evaluated, and compared using a variety of parameters and methods for model validation and potential refinement, as described in the sections below.

2.3.2.1 ET-IDC

As described in **Section 1.3.2**, the 2020 Report delineated six reference ET, or ETo[15], zones to account for the spatial variability in ETo occurring in the Study Area. The zones generally correspond to decreasing ET demands as elevation increases moving eastward in EDC. Daily ETo for each zone was computed by multiplying daily ETo observed at the Fair Oaks California Irrigation Management Information Systems (CIMIS)[16] station by a zone-specific adjustment factor (**Table 2-2**). The zone adjustment factors were computed by dividing the long-term average ETo from Spatial CIMIS for each zone by the long-term average Spatial CIMIS[17] ETo at the Fair Oaks CIMIS station location.

Table 2-2. ET_o Zone Adjustment Factors (EDWA, 2020).

	ET_o Zone	Zone Adjustment Factor
Eastern EDC	45	0.809
	47	0.854
	49	0.879
	51	0.921
	53	0.956
Western EDC	55	0.987

Then, daily ET values were calculated by multiplying the daily ETo values in respective zones with locally calibrated monthly crop coefficients (Kc). The methods for calculating and calibrating monthly Kc values are described in detail in Appendices C and D of the 2020 Report. Briefly, the crop coefficients were quantified using METRIC (Mapping EvapoTranspiration with high Resolution and Internalized Calibration), a surface energy balance model, and meteorological data and Landsat images for the 2017 calendar year and irrigation season. Ultimately, daily ET (ET-IDC) was calculated for the 2020 Report by multiplying ETo from the Fair Oaks CIMIS station by the ETo Zone Adjustment Factor and the locally-calibrated Kc from the 2017 METRIC analysis. The IDC model was updated through 2024 so that average crop-specific model results for the E50H model run could be extracted for 2024 and directly compared to other Study data collected during the same time period.

[15] ETo is the ET of well-watered actively growing closely clipped grass that is completely shading the soil. More information about ETo is available at: https://cimis.water.ca.gov/Resources.aspx#
[16] More information about CIMIS is available at: https://cimis.water.ca.gov
[17] More information about Spatial CIMIS is available at: https://cimis.water.ca.gov/SpatialData.aspx

2.3.2.2 ET-OpenET

To evaluate ET, data from OpenET[18] (which were not available when the 2020 Report was developed) were acquired for direct comparison to the ET results from the 2020 Report. OpenET utilizes satellite-based remote sensing approaches to quantify and provide ET data to improve water management across the western United States. This remote sensing approach quantifies actual ET on a discrete spatial scale on both daily and monthly timesteps. The data obtained from OpenET (ET-OpenET) were directly compared to the ET results produced in the 2020 Report (ET-IDC).

2.3.2.3 ETAW-IDC

For the parameters described above (ET-IDC and ET-OpenET), the total ET from the 2020 Report and the OpenET data in this Study can be directly compared. However, it is worth noting that total ET is the combined ET from all available water, regardless of source. The two sources of water in an irrigated landscape are typically precipitation and applied water for irrigation[19]. The 2020 Report, using the IDC model, distinguished between and separately accounted for ET from precipitation (ETPR) and ET from applied water (ETAW) with the sum of ETPR and ETAW equaling total ET. The crop-specific average ETAW results from the IDC model (ETAW-IDC) for the E50H model run were extracted for comparison to and evaluation against the flow paths and parameters described in subsequent sections.

2.3.2.4 ETAW-OpenET

In order to calculate ETAW requirements using available data from OpenET (ET-OpenET), the ETPR from the IDC model (ETPR-IDC) was subtracted from ET-OpenET. In other words, the amount of total ET from OpenET met by applied water (ETAW-OpenET) is equal to ET-OpenET minus ETPR-IDC. Individually quantifying ETAW-IDC and ETAW-OpenET allowed for direct comparison of the two sets of values for model validation and potential refinement.

2.3.3 Consumptive Use Fraction (CUF), or Irrigation Efficiency (IE)

In an agricultural context, the consumptive use fraction (CUF) is a parameter that describes how much applied irrigation water is consumed by crops for growth relative to the total amount of water applied for irrigation. It was described as irrigation efficiency in the 2020 Report. The CUF is the ratio of evapotranspiration of applied water (ETAW) to applied water (AW) with ETAW in the numerator and AW in the denominator (ASCE 2016). For example, if 100 acre-feet (AF) of water were AW and 85 AF were consumed as ETAW, this would result in a CUF value of 0.85 (i.e., 85/100).

The CUF is influenced by a variety of factors including irrigation method, irrigation system distribution uniformity, grower practices, and field-specific conditions. All else being equal, lower efficiency irrigation methods, such as overhead sprinklers or flood irrigation, would be expected to result in a lower CUF than more precise irrigation methods, such as drip emitters or micro-sprinklers. Typical values for CUF range from around 0.60 to 0.90 for less efficient applications of AW to more efficient applications (see **Section 3.3.3** for more details).

A related parameter to the CUF is distribution uniformity (DU), which is a metric describing how evenly water for irrigation is applied across an area and is expressed as a percentage (with 100% representing

[18] More information available at: https://etdata.org

[19] A potential third source of water in an irrigated landscape is shallow groundwater within or close enough to the root zone to be accessible to plants. From grower coordination and review of in-field conditions, this was determined to not be present in any of the participating fields during the Study.

perfect DU, although that value is not practically attainable). DU testing was completed as part of field data collection (as described in **Section 2.3.3.4** below). In the absence of deficit irrigation, DU values tend to represent the upper limit of a possible CUF value, with CUF values tending to be slightly lower and the difference between the two being an indicator of irrigation management proficiency.

Additionally, a literature review to compile published values or results for the CUF, or related parameters such IE or application efficiency (AE) was completed. The subsequent sections describe the methodologies used to quantify the CUF as part of the 2020 Report and the current Study.

2.3.3.1 CUF Assumed to be 0.8 (CUF-0.8)

As part of the 2020 Report, the CUF was assumed to be equal to 0.80 for all crops, irrigation methods, and other conditions and characteristics. It was acknowledged that this value is potentially conservative (i.e., higher than many actual CUF values), but is considered a reasonable assumption for planned irrigated agricultural growth in EDC. It was also acknowledged that in reality this value is variable depending on specific conditions and characteristics, but an assumed value was required for future planning (EDWA, 2020). An important aspect of the current Study is to calculate CUF values based on data collected as part of the Study and to perform Distribution Uniformity (DU) testing, use the results of each to evaluate typical CUF values and variability in CUF for existing irrigated agriculture on the West Slope, and to compare calculated CUF values to the 0.80 assumed CUF value. Each of these aspects of the Study are described in more detail below.

2.3.3.2 CUF Based on ETAW-IDC and AW-WM (CUF-IDC)

As described above, an investigation was undertaken during the development of the 2020 Report to determine if there were readily available AW data to use to compare against the ETAW calculated by the IDC model and the assumption of a universal CUF equal to 0.80. Unfortunately, no available AW data were identified, which in large part led to this Study and the collection of AW data (as described in **Section 2.3.4**).

The CUF was calculated based on the crop-specific average ETAW for 2024 extracted from the IDC model developed for the 2020 Report (ETAW-IDC, described in **Section 2.3.2.3**) divided by the actual AW measured using water meters (AW-WM, described in **Section 2.3.4.1**). This calculation incorporates actual in-field measurements of AW to evaluate the variability in CUF values across participating irrigation units in EDC and can be directly compared to the 2020 assumption of a CUF of 0.80.

2.3.3.3 CUF Based on ETAW-OpenET and AW-WM (CUF-OpenET)

The CUF was also calculated based on the ETAW quantified using data available from OpenET (ETAW-OpenET, described in **Section 2.3.2.4**) divided by the actual AW measured using water meters (AW-WM, described in **Section 2.3.4.1**). This calculation can be directly compared to the 2020 assumption of a CUF of 0.80 and the values calculated using IDC model results (CUF-IDC).

2.3.3.4 CUF Upper Limit from Distribution Uniformity (DU) Testing (CUF-DU)

Distribution uniformity (DU) is a metric describing how evenly water for irrigation is applied across an area, and it is calculated as the average irrigation depth of the lowest 25% of a field divided by the average irrigation depth of the entire field (ASAE, 1990). It is not equivalent to the consumptive use fraction (CUF), a measure of how efficiently AW is able to meet ETAW, but it is correlated (as explained below). DU is expressed as a percentage, with 100% representing completely even distribution of applied water, although this percentage is not practically attainable. DU values vary based on irrigation method, irrigation system design, irrigation system maintenance, field topography and slopes, and other factors. In general, values above 90% are considered excellent, 80% to 90% are good, 60% to 80% are fair, and below 60% are poor.

There is typically a positive correlation between DU and CUF: in general, the higher the DU value is, the higher the CUF value will be as well. This is because the DU value usually sets the upper limit of the CUF value. A high DU accompanied by a high (although lower than DU) CUF represents high management proficiency (i.e., the irrigation system is being managed close to its potential). A high DU and low CUF indicates that the irrigation system components are well-maintained, but there is inadequate management in the timing and extent of irrigation relative to crop ET demands. There can also be exceptions to DU being greater than CUF: when deficit irrigation is practiced it is possible for the CUF value to exceed the DU value.

The DU was tested through a random sampling of irrigation emitter/sprinkler output across the irrigated area[20]. A graduated cylinder (or other type of container with known volume at different levels) was used to directly measure the volume of water captured at each randomly selected location over time, and the volume measured was divided by time elapsed to calculate a flow rate for that location (**Figure 2-3**). The sampling targeted at least 25 individual measurements per DU test, with relatively larger irrigated areas including greater than 25 measurements. The objective of field data collection was to complete at least one DU test for every irrigation unit, although this was dependent on timing of irrigation and field visits to each site.

[20] DU tests can also include measurements of irrigation system pressures throughout the system, but this was not included in the current Study due to desire to (1) make DU testing as efficient as possible and (2) not directly alter or impact participating grower irrigation systems (the pressure test requires creating a hole in irrigation lines to test system pressure in different locations; each hole then needs to be carefully filled to prevent leaks).

Figure 2-3. Distribution uniformity (DU) testing example, showing the volume measured at a randomly selected drip emitter over a recorded period of time, within a vineyard irrigated by a drip irrigation system.

After completing the DU test and collecting the data, the DU result can be calculated. As defined above, DU (expressed as a percentage) is equal to the average flow rate of the lowest 25% of emitters/sprinklers divided by the average flow rate of all emitters/sprinklers, multiplied by 100. As described above, DU values are dependent on irrigation method (among other factors) and tend to increase as the ability to precisely apply irrigation water increases. For example, the three most common irrigation methods encountered in EDC through interactions with growers were overhead sprinkler, micro-sprinkler, and drip irrigation systems. The DU was expected to increase across these three, with overhead sprinklers being the least uniform application of AW and drip irrigation being the most.

The DU results can be directly compared to the CUF results from the 2020 Report and from the Study (see prior sections in **Section 2.3.3**) to see how well values align, although as described above, it is not a direct comparison.

2.3.4 Applied Water

Applied water for irrigation is what enables agricultural production in areas where precipitation alone does not supply sufficient water to meet crop water demands. In EDC, applied water requirements can vary substantially based on a variety of factors such as crop type, soil type, elevation, irrigation method, irrigation system management, and more. Understanding the variability in timing and volume of applied water across the diversity of agricultural crops and practices in EDC, especially relative to estimates of applied water from the 2020 Report, is one of the primary objectives of the Study. The estimated applied water volumes from this Study will inform long-term water resources planning for irrigated agricultural growth.

As part of the 2020 Report, applied water was calculated as the ETAW extracted from the IDC model divided by an assumed consumptive use fraction (CUF), or irrigation efficiency, of 0.80 (or 80%). As noted in the 2020 Report, this 0.80 assumption is relatively high compared to area-wide averages observed elsewhere in California, but was considered a reasonably conservative expectation for planned irrigated agricultural growth in EDC. Validation of AW estimates from the 2020 Report was attempted, but no suitable records could be located at that time, thus leading to this Study.

2.3.4.1 AW Based on ETAW-IDC (AW-IDC)

As described above and in the 2020 Report, the IDC model developed for the 2020 Report estimated ETAW (ETAW-IDC, see **Section 2.3.2.1**), which was divided by an assumed CUF value of 0.80 (CUF-0.8, see **Section 2.3.3.1**) to calculate estimated applied water (AW-IDC). The methodologies and assumptions were exactly the same as those used in the 2020 Report. However, the IDC model was updated with P and ET inputs through 2024 and the AW-IDC values produced are for the same time period and can be directly compared to other AW data (e.g., AW-WM).

2.3.4.2 Applied Water Measured with Water Meters (AW-WM)

Applied water data for the participating fields in this Study was measured using totalizing water meters, or flowmeters (**Figure 2-4**). Some growers already had totalizing water meters that were installed prior to the Study that directly measure their applied water volumes for agriculture over time; observations from these were collected and the resulting data were directly used. Some potential growers without existing water meters had them provided and installed as part of the Study (as described above) to initiate measurements of applied water volumes for the Study. Lastly, some of the participating growers were within the El Dorado Irrigation District (EID), which uses totalizing water meters to measure deliveries to customers to enable volumetric billing.

For participating growers within EID, some of these locations include water meters that solely measure water that will be applied for purposes of irrigation of agriculture. However, other water meters also measured water delivered for a variety of other purposes such as indoor uses (domestic, commercial, or industrial uses), landscape irrigation, or maintenance of surface water bodies. In some cases where the EID meter measured a volume of water for multiple purposes, an additional water meter that solely measures agricultural water use had already been installed by the grower or was installed for use in the Study. In other cases, the volume of water for purposes other than irrigation of agriculture was estimated and subtracted from the total volume to calculate the volume used for agriculture, as documented in **Appendix C**. In the latter cases, the large majority of the total volume was for irrigation of agriculture (over 90% of the volume on average) for every included irrigation unit. In addition to recording observations of EID water meters wherever possible during field visits in 2024, water meter reading records were also obtained from EID for 2024 and prior years, as available.

The applied water observed in the field (or provided by EID) as part of this Study can be directly compared to the estimates of applied water from the 2020 Report in order to evaluate the 2020 approach and assumptions for either validation or potential refinement.

Figure 2-4. Water meter located within a concrete vault; periodic observations of these were recorded to track applied water volumes over time.

2.3.4.3 AW Based on ETAW-OpenET (AW-OpenET)

As described **Section 2.3.2.4**, ETAW using OpenET data was calculated (ETAW-OpenET). This was divided by the assumed CUF value of 0.80 (CUF-0.8, see **Section 2.3.3.1**) to calculate estimated applied water (AW-OpenET) based on OpenET data instead of IDC model results.

2.3.4.4 AW Based on ETAW-OpenET and CUF-DU (AW-OpenET-CUF-DU)

To evaluate how a different CUF value would impact estimated AW requirements, the median value from DU testing was utilized as the assumed CUF (CUF-DU, see **Section 2.3.3.4**) to convert from ETAW (ETAW-OpenET) to AW (AW-OpenET-CUF-DU) by dividing the ETAW by the CUF.

2.3.4.5 Water Meter Comparison Flow Measurements

In addition to collecting totalizer readings of volume over time from each water meter included in the Study, the water flow rate was also recorded if site visits were performed while irrigation was occurring. Some water meters included a direct readout of flow (typically in gallons per minute) that could be recorded. For water meters that only included a totalizer reading, data were collected so that the flow rate could be calculated: the totalizer volume was read twice while noting the time between readings, which allows for a calculation of the average flow rate between readings.

The piping configuration in the vicinity of water meters (if above ground) was also reviewed to determine if it would be possible to perform an independent flow measurement for comparison to the flow rate of the water meter. If water was being applied for irrigation during site visits and if site conditions allowed, an independent flow measurement was completed using a portable transit time flowmeter (Fuji Electric Portaflow-C, FSC4) for comparison to the flow rate measured by the permanent water meter to evaluate water meter measurement accuracy. The data collection objective was to perform at least one comparison flow measurement for every water meter where it was feasible. **Figure 2-5** depicts one of these comparison flow measurements being performed.

Figure 2-5. Water meter and portable ultrasonic transit time flowmeter measuring the same flow through PVC irrigation pipelines as an evaluation of water meter accuracy. The pipeline furthest right measures all water inflow and includes a permanent water meter; valves can be used to control irrigation to specific blocks on all pipes further to the left. Note that valves on all irrigation blocks except 5 and 6 are closed, and block 5 was closed at another valve further downstream (confirmed in the field), so the flow past the portable meter installed on the block 6 line was equal to the total inflow measured by the permanent water meter.

2.3.5 Historical Data Analysis

A historical analysis (using data from 2006 through 2024) was conducted to evaluate the annual variability of applied water (AW), evapotranspiration (ET), and precipitation (P) over time and to compare 2024 to other years to see how representative it was of average conditions over time. Using the same methods described in the sections above, historical applied water data were obtained from EID water meter records (which were often available over multi-year periods) and processed for applicable irrigation units. This processing included estimating and accounting for water used for purposes other than for irrigation of agriculture (see **Appendix C**). For the irrigation units with historical applied water data, P and ET data were also obtained from PRISM and OpenET, respectively. While P and ET data were available across the entire Study Area for the full time period, AW data were limited by EID water meter record availability. Lastly, the evaporative index (i.e., ET / P) was calculated and evaluated to see how water demands and supply of water from precipitation vary over time and how 2024 compares to the long-term average.

2.3.6 In-Field Soils Data Collection

Estimates of ET are dependent on the root-zone modeling of soil water holding capacity, which is heavily influenced by soil properties, particularly soil texture. Initial geospatial soil information can be processed for all irrigated fields using the Natural Resource Conservation Service's (NRCS) Soil Survey Geographic Database (SSURGO[21]). For example, the original field-scale soil properties used in the IDC model were estimated using weighted average sand, silt, and clay percentages from the SSURGO dataset. Given the significant impact soil properties can have on applied water requirements, the field data collection undertaken during the Study included collecting soil samples, analyzing them in a lab, and comparing them to the SSURGO soil data.

DE collected soil samples from 13 fields throughout the Study Area. A total of five soil samples were collected within each field each at a depth between 8 and 12 inches. The samples were aggregated together and sent to the University of California (UC) Davis Analytical Laboratory for analysis. Average percentages of sand, silt, and clay between 0 and 10 inches below the soil surface for the same fields were estimated from the SSURGO dataset for comparison purposes. More details on the methods and results of this analysis can be found in **Section 3.3.5** and **Appendix D**.

[21] More information about the Soil Survey Geographic Database (SSURGO) can be found here: https://www.nrcs.usda.gov/resources/data-and-reports/soil-survey-geographic-database-ssurgo.

3 Results and Discussion

3.1 Grower Recruitment and Coordination and Selection of Participating Lands

3.1.1 Coordination with Project Collaborators and Direct Grower Outreach

The coordination with project collaborators and direct grower outreach were the tasks that led to connecting with active growers in EDC, explaining the Study and its objectives, and resulting in their participation. The project collaborators included:

1. El Dorado County Agriculture Department (EDC Ag. Dept.)
2. El Dorado Farm Bureau (EDFB)
3. University of California Cooperative Extension (UCCE)
4. Irrigation Management Services (IMS) Contractors
5. El Dorado Wine Grape Growers Association (EDWGGA)
6. Apple Hill Growers Association

Coordination efforts with project collaborators are described in more detail in **Appendix A**. Through project collaborators, the opportunity to participate in the Study was shared with an estimated 100 to 200 growers. Additionally, direct grower outreach was conducted with roughly 75 individual growers (many of these growers were also contacted through a project collaborator).

3.1.2 Selection of Participating Lands

In total, there were 22 unique growers who met all of the eligibility criteria and agreed to participate and include their irrigated lands in the Study. Some growers had only one field (or set of fields) included, while others had multiple fields (or sets of fields). In total, there were 41 unique fields identified for inclusion in the Study. Each of these were linked to one or more water meters to form irrigation units. These are summarized below in **Table 3-1**, which organized fields by crop category and shows a field count, field count percentage, approximate acreage, acreage percentage, and average field size.

Table 3-1. Summary of all participating lands in the Study, including cropping, field count, and size.

Crop Category	Field Count	Field Count %	Approximate Acreage	Acreage %	Average Field Size (ACRES)
Apples	5	13%	19	3%	3.7
Blueberries	1	3%	9	1%	9.0
Christmas Trees	3	5%	12	2%	4.0
Miscellaneous Deciduous	5	13%	56	8%	11.1
Mixed Cropping	4	10%	44	6%	10.9
Truck Crops	3	8%	7	1%	2.2
Vineyard	20	50%	566	80%	28.3
Totals or Average	***41***	***100%***	***711***	***100%***	***17.4***

The largest crop category of participating lands were vineyards, which are the largest crop by acreage based on most recently available cropping data for EDC. Vineyards represented half of the fields, but due to inclusion of some larger vineyard areas, represented roughly 80% of the total acreage included in the Study. The next largest crop categories by field count were apples, miscellaneous deciduous, and mixed cropping. The additional crop categories (blueberries, Christmas trees, and truck crops) represented the smallest portion of the Study lands from both a field count and acreage perspective.

The miscellaneous deciduous crop category included a variety of different miscellaneous deciduous crops (sometimes multiple within a single irrigation unit). These crops included cherries, peaches, pears, persimmons, plums, nectarines, and walnuts. The mixed cropping category represents a set of fields with multiple crops for which the water applied to each individual crop could not be distinguished, so all crops were included together in one mixed cropping irrigation unit. These irrigation units primarily included crops from the other crop categories, but also included a few new crop types including citrus, olives, and raspberries.

One important note is that no irrigated pasture was included in the participating lands for the Study. This crop category was identified as one of the five major crops in EDC as part of the 2020 Report; historically, it was the largest crop from an acreage perspective, but the irrigated pasture acreage in EDC has been decreasing over time (EDWA, 2020). Specific efforts both through project collaborators and direct grower outreach were undertaken to coordinate with active growers with irrigated pasture to include them in the Study. However, no growers were found that met all eligibility criteria and were willing to participate in the Study. Based on recent data, both livestock and grain and hay production remain a major part of EDC's agricultural portfolio from both a financial and overall acreage standpoint (EDAC, 2023; DWR, 2023).

Finally, as described in **Section 2.1.2**, even if a grower and their associated irrigated lands were initially selected for inclusion in the Study, the data collected may not be able to be included in the final dataset and results due to data quality issues. Of the 41 irrigation units initially configured for inclusion in the Study, a total of 13 (32%) were excluded from the final dataset. Data quality issues that resulted in exclusion included poor data records from water meters (e.g., malfunctioning or broken water meters) and uncertainty in estimating the water volume for irrigation of agriculture for EID meters (see **Appendix C** for more information). The 28 irrigation units included in the final dataset are shown below in **Table 3-2**. Multiple large vineyards were excluded from the final dataset, which significantly reduced the overall included acreage, but increased the representative percentages of total acres of crops in other crop categories. However, vineyards remained the largest crop category from both a field count and acreage perspective. The overall irrigated acreage in EDC in 2023 was 3,887 AC (EDAC, 2023); based on this, the 255 acres included in the Study results represent approximately 7% of the total irrigated lands in EDC. The crop distribution is roughly consistent with the current distribution of irrigated acreage in the West Slope based on the 2020 Report.

Table 3-2. Summary of participating lands in the Study included in the final dataset and results, including cropping, field count, and size.

Crop Category	Field Count	Field Count %	Approximate Acreage	Acreage %	Average Field Size (ACRES)
Apples	3	11%	11	4%	3.7
Christmas Trees	3	11%	12	5%	4.0
Miscellaneous Deciduous	3	11%	27	11%	9.0
Mixed Cropping	4	14%	44	17%	11.0
Vineyard	15	54%	161	63%	10.7
Totals or Average	***28***	***100%***	***255***	***100%***	***9.1***

3.1.3 Ongoing Outreach during In-Field Data Collection, Data Analysis, and Documentation

Ongoing outreach and coordination with participating growers throughout the Study increased the quality of the data being collected and improved Study results. Participating growers were able to answer clarifying questions and provide more information about their irrigated fields, crops, water use, and more through these efforts.

3.2 Overview of Study Design and Data Collection

The completion of the study design and identification of key flow paths and parameters allowed for data collection, processing, analysis and comparison to the 2020 Report as described in subsequent sections. The study design and data collection were described in **Section 2.2**.

3.3 Data Collection, Processing, Analysis, and Comparison to the 2020 Report

3.3.1 Precipitation

The precipitation data from PRISM and NOAA weather stations were downloaded and processed in preparation for direct comparison for model review, as described in **Section 2.3.1**. The PRISM results for the 2024 calendar year are shown below in **Figure 3-1**. The trend of increasing precipitation with increasing elevation as one travels further east in EDC can be clearly seen. There are also four NOAA weather stations with precipitation gauges depicted on the map with the station names below:

1. COOL 2.0 ENE
2. PLACERVILLE 0.9 NE
3. PLACERVILLE 3.7 SW
4. PLACERVILLE IFG

During 2024, each of these weather stations included at least one complete monthly record (i.e., a month without any missing data and without any questionable data). PLACERVILLE 3.7 SW included a complete record for all of 2024; it measured 33.4 IN of precipitation during the year. The PRISM grid cell within which it is located is estimated to be 37.6 IN of precipitation (a 12.6% difference, relative to the NOAA station). The evaluation of precipitation data available from NOAA is described in more detail in **Appendix B**.

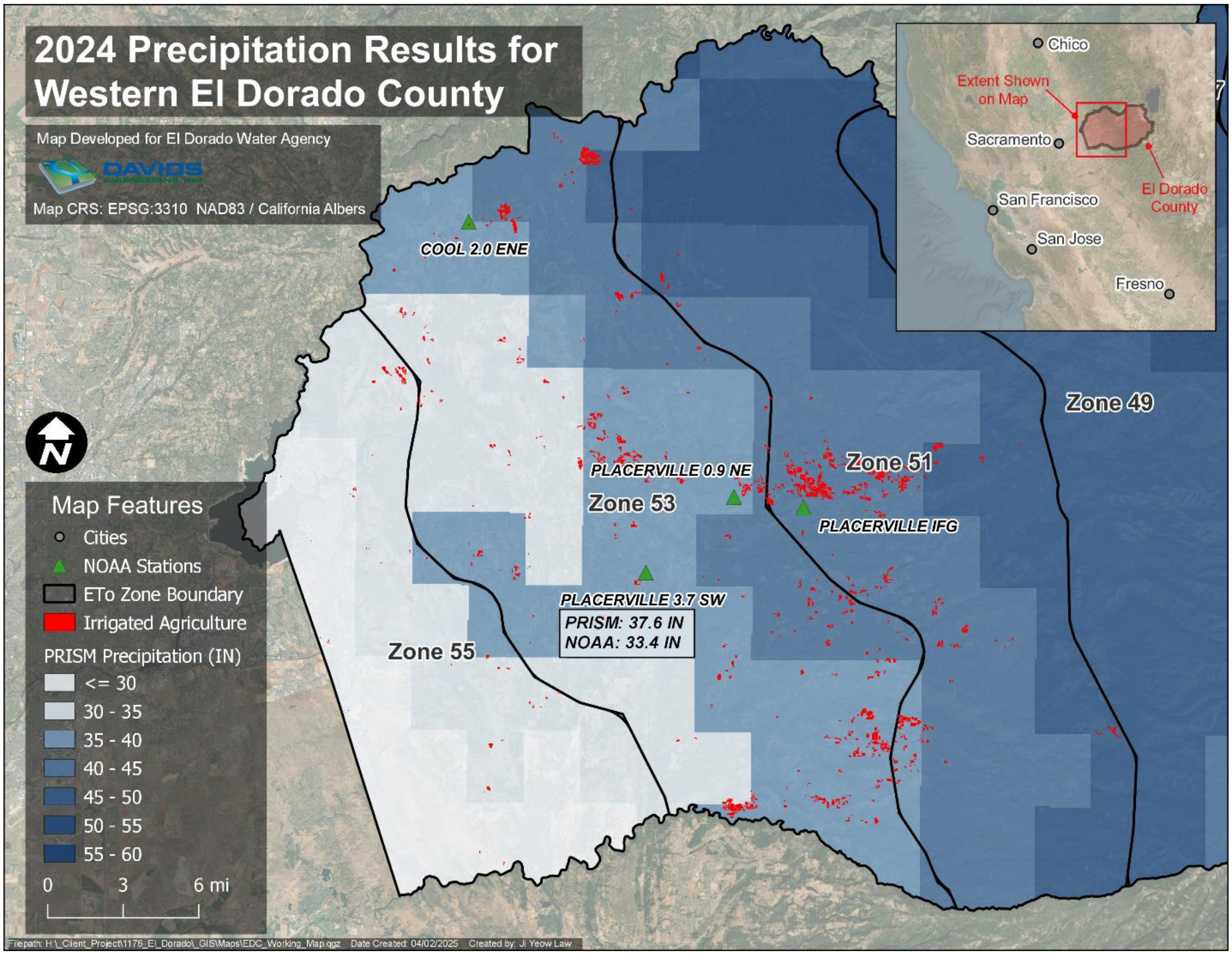


Figure 3-1. Spatial annual precipitation results for 2024 calendar year across the ETo zones in western El Dorado County, where existing irrigated agriculture is located. The annual precipitation increases with elevation moving from west to east. The four NOAA precipitation stations depicted had at least one complete monthly record; station PLACERVILLE 3.7 SW had a complete record for all of 2024 with a total precipitation of 33.4 IN.

Historical data from prior years for these four NOAA precipitation stations (P-NOAA)[22] within western EDC were also considered for comparison to PRISM data (P-PRISM) for the same periods. On a monthly basis, a total of 227 (i.e., n) complete monthly records were identified in the NOAA data. These were directly compared to the PRISM estimates for the same month and year for the grid cell within which the NOAA station is located. The results of this are depicted in **Figure 3-2** in a scatterplot. The 1:1 line is shown as a solid gray line; any points that fall on this line show perfect agreement between NOAA and PRISM data. The regression analysis to determine line of best fit shows results in a slope (i.e., m, in $y = mx$) equal to 1.025, meaning that based on the included data, the PRISM model results tend to be 2.5% higher than the NOAA measured precipitation (see red dashed line). Based on this slope, for a month with 10 IN of rain observed by NOAA, the PRISM value would typically be equal to 10.25 IN. The coefficient of determination (R^2) is a measure of how closely the regression line fits the data in the

[22] Other NOAA precipitation stations were also included in the historical analysis, although no other complete monthly records were identified.

scatterplot (with a value closer to 1 being indicative of a better fit), and the R^2 is close to one with a value of 0.96.

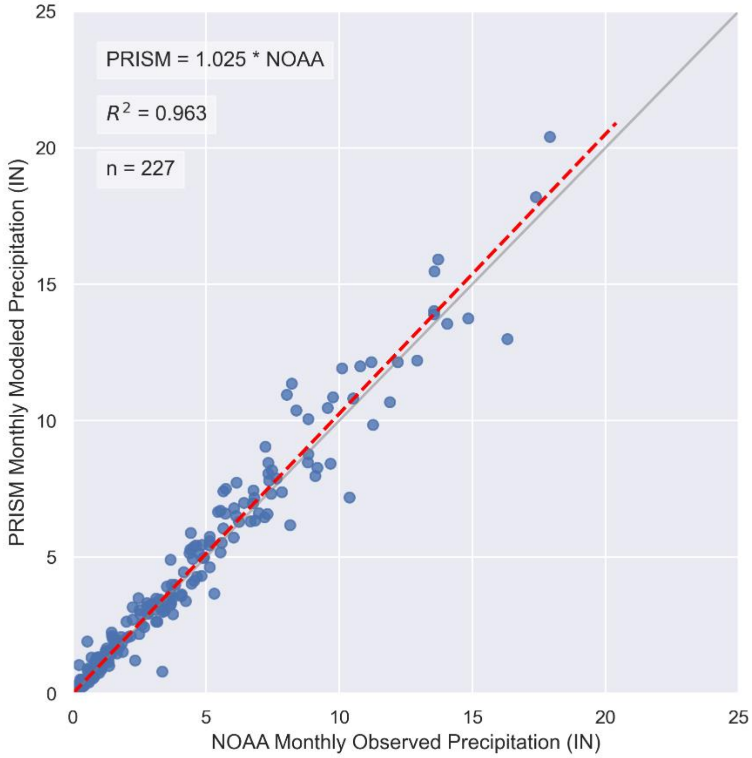


Figure 3-2. Scatterplot depicting relationship between measured monthly precipitation from NOAA stations (P-NOAA) and modeled monthly precipitation from PRISM (P-PRISM). Based on the regression, the PRISM values tend to be slightly higher than NOAA, but the two datasets closely align (R^2 = 0.96, m = 1.025).

The overall average values based on these 227 monthly records were also calculated, with average P-PRISM equal to 3.77 IN and P-NOAA equal to 3.64 IN. Based on this comparison, P-PRISM is approximately 4% greater than P-NOAA.

As described in **Section 2.3.1**, precipitation generally serves as the primary water source for agriculture in western EDC, and it is critical to accurately quantify it for water planning. These results provide evidence supporting the accuracy of the PRISM dataset for western EDC and validating its suitability as the data input for the IDC model developed to plan for future applied water requirements. Although differences are observed in some months at some sites and during 2024 between PLACERVILLE 3.7 SW and the underlying PRISM cell, overall there is close alignment between these two datasets. Additional information about this analysis is available in **Appendix B**.

3.3.1.1 P-PRISM

As described above in **Section 3.3.1**, P-PRISM values were extracted and compared to P-NOAA values at four stations. Based on the regression analysis performed, P-PRISM tended to be 2.5% higher than P-NOAA based on the regression analysis, and P-PRISM tended to be 4% higher than P-NOAA based on a comparison of overall average values for the 227 months. These results validated the accuracy of the PRISM dataset as a precipitation input for the IDC model.

3.3.1.2 P-NOAA

See **Sections 3.3.1** and **3.3.1.1** for a presentation and discussion of the results for P-NOAA.

3.3.1.3 ETPR-IDC

Although technically an ET output, the evapotranspiration of precipitation (ETPR) is directly related to total precipitation amounts. ETPR was extracted from the IDC model results (ETPR-IDC). The ETPR values were variable across the irrigated and cropped lands due to differences in geographic location, soils, and crop type, but when the results were combined to calculate a representative overall ETPR value, the result for the 2024 Study period was 17.1 IN. The ETPR-IDC values were used for calculation of both ETAW-IDC and ETAW-OpenET.

3.3.2 Evapotranspiration (ET)

3.3.2.1 ET-IDC

As described in **Section 2.3.2.1**, in order to quantify the total ET demands from the 2020 modeling approach for the 2024 calendar year (ET-IDC), the IDC model developed as part of the 2020 Report was updated through 2024. The modeling period from the 2020 Report was for 1998 to 2017 (20 years), and model inputs for the years of 2018 through 2024 were developed and added to the model as part of the Study (updating the model period to 27 total years). Crop-specific average ET results in 2024 were then extracted for evaluation and analysis. Aggregating values for individual fields to calculate a representative overall ET value resulted in ET-IDC equal to 24.3 IN. This value is directly compared to OpenET results in the next section.

3.3.2.2 ET-OpenET

OpenET data results for the 2024 calendar year are shown below in **Figure 3-3**. As described in **Section 2.3.2.2**, the data shown are quantified values of actual ET on a discrete spatial scale. Although ETo decreases moving eastward and higher in elevation, there is no discernible pattern of decreasing ET; if anything, the ET values tend to increase moving eastward. This is due to multiple factors, but two important ones include land use (or land cover in undeveloped areas) and water availability. The western edges of EDC are grass or shrublands with shallow soils and roots and lower ET; as the elevation increases moving the east, there is a transition into oak woodland areas and then into pine forests. These plants have increasing ET demands, due to their overall size and also their deeper root systems that are able to access water in the soil deeper beneath the ground surface. Also, in undeveloped areas without any applied water, the only source of water is precipitation. The increasing precipitation moving eastward in EDC provides more water to plants to support ET demands.

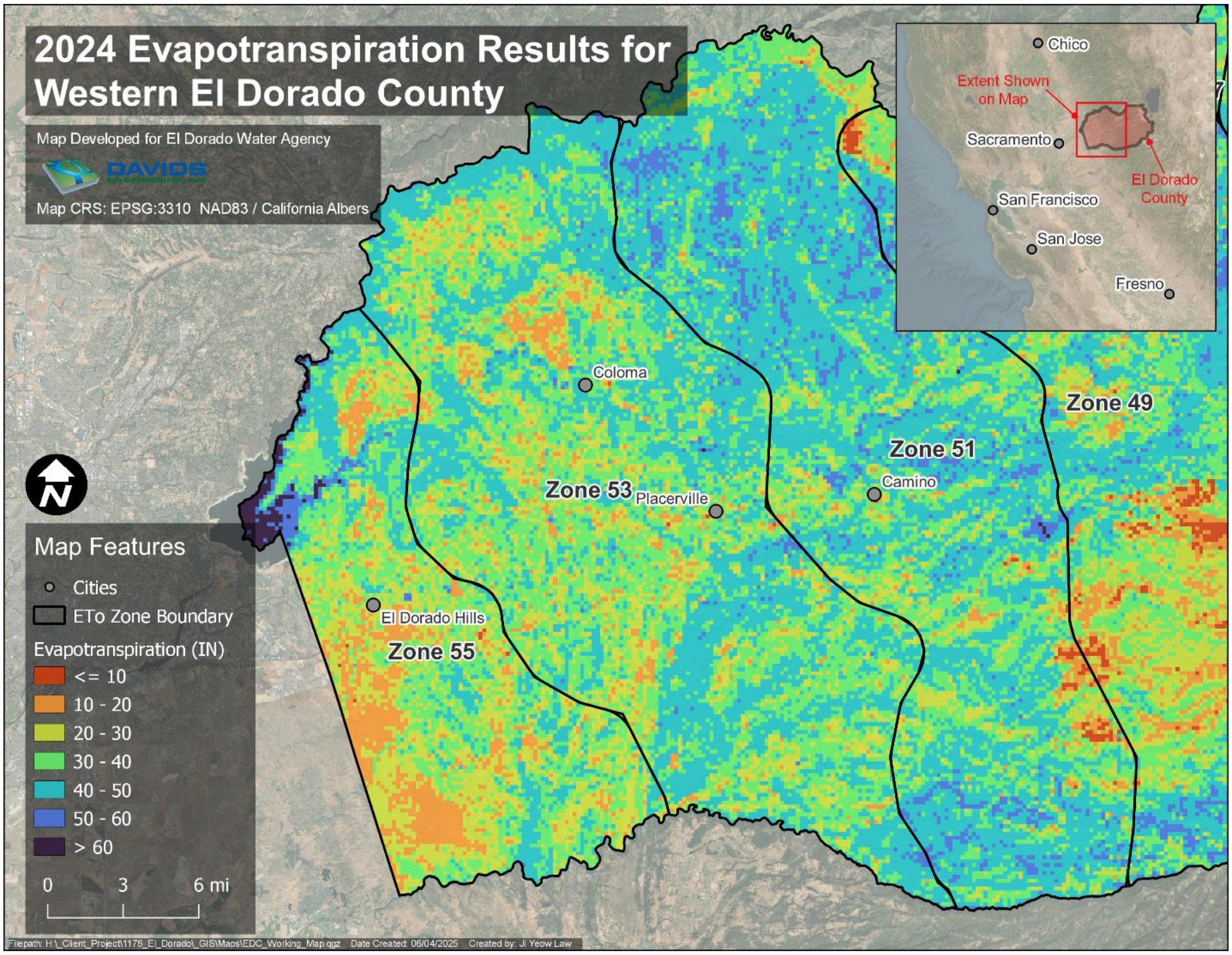


Figure 3-3. Spatial annual ET results for 2024 calendar year across ETo zones in western El Dorado County, where irrigated agriculture is located. As shown, results range from less than 10 IN to greater than 60 IN.

In total, there were 28 irrigation units with results included in this analysis: 15 were vineyards, three were apples, three were Christmas trees, and seven were miscellaneous deciduous (or mixed cropping). The average total ET values for each crop type were calculated using data extracted from the IDC model (ET-IDC, see **Section 3.3.2.1**). The total ET values from OpenET for each irrigation unit were also compiled (ET-OpenET). A comparison between ET-IDC and ET-OpenET is depicted in **Figure 3-4**, with the ET-IDC results appearing as a single average value (the dashed line) and the distribution of ET-OpenET results for all irrigation units within a crop type (e.g., n = 15 for vineyards) shown as a boxplot[23].

[23] A boxplot depicts the full distribution of a dataset. Boxes show the interquartile range between the first and third quartiles (25th and 75th percentile, respectively) of the dataset, while whiskers extend to show minimum and maximum values of the distribution. Circles shown beyond the whiskers represent points considered outliers; they are more than 1.5 times the interquartile range away from the first or third quartiles. The middle line of a boxplot shows the second quartile (50th percentile), or median, of the dataset. For a given scale, a large boxplot shows a relatively higher variability in the data distribution, while a smaller boxplot (which can more closely resemble a line than a box in some instances) shows a relatively lower variability.

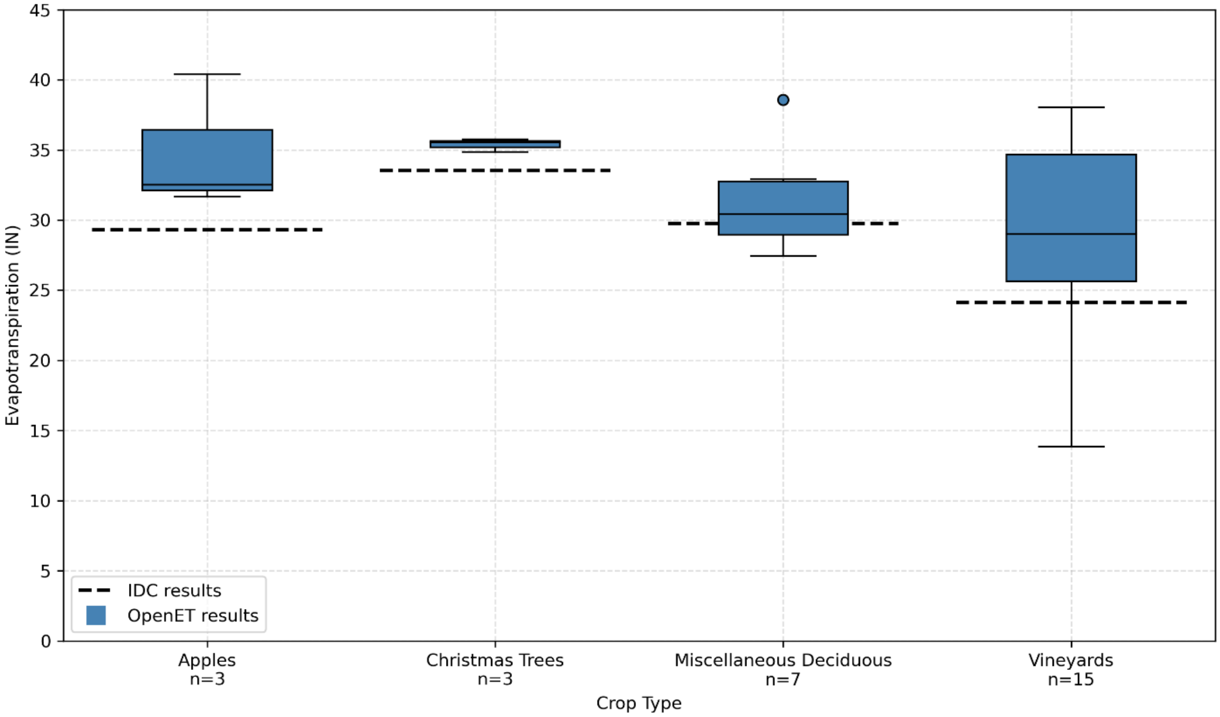


Figure 3-4. Comparison of OpenET data (boxplots) to average IDC model results (dashed line) for the four major crops with participating lands in 2024. The sample size of irrigation units for each crop type is shown along the x-axis. Note that mixed crop irrigation units are classified under miscellaneous deciduous in these results.

Overall, ET values from OpenET were higher than those modeled through IDC as part of the 2020 Report. For apples and Christmas trees, all OpenET values are higher. For vineyards and miscellaneous deciduous, the IDC values are within the range of values from OpenET, although over 75% of the vineyards have OpenET values higher than the IDC values. These results indicate that the IDC model may be underestimating total ET to differing degrees across the major crop types, although there is uncertainty in the results of both the IDC model and the OpenET data. It is difficult to accurately quantify any water flow path, and ET is potentially the most difficult to accurately quantify. The 2020 Report compared 2017 METRIC results with ground-based eddy covariance/surface renewal ET estimates (based on an existing dataset) for a mature vineyard and calculated a 17% difference between the ET results for the two methods, which each have associated uncertainties (EDWA, 2020). OpenET data has also conducted its own accuracy assessment based on comparison of its remote-sensing data to over 150 ground-based ET measurements, and it calculated a mean absolute error (MAE) for croplands of 8.9% on an annual basis, a MAE of 13.2% on a growing season basis, and an MAE of 16.6% on a monthly basis (OpenET, 2025). Ultimately, aggregating values to calculate a representative overall ET value resulted in ET-OpenET equal to 27.9 IN, or 14.8% higher than ET-IDC.

Finally, as described earlier, the comparison above is a comparison of total ET values (combined ET from all available water, regardless of source). The two sources of water for participating in EDC are precipitation and applied water for irrigation, and some portion of total ET is met by both, dependent primarily on the magnitude and timing of precipitation in any given year. The quantification of ETPR was described in **Section 3.3.1.3** and the quantification of ETAW is described in subsequent sections.

3.3.2.3 ETAW-IDC

As described **Section 2.3.2.3**, the IDC model tracks ETAW and ETPR separately, so that each can be aggregated and evaluated independently. Total ET is calculated as the sum of each. Crop-specific average ETAW was extracted from the IDC model (ETAW-IDC). The ETAW values were variable across the participating lands due to differences in geographic location, soils, and crop type, but when the results were combined to calculate a representative overall ETAW value, the result for the 2024 Study period was 7.2 IN.

3.3.2.4 ETAW-OpenET

As described in **Section 2.3.2.4**, the ETAW from OpenET (ETAW-OpenET) was calculated as the ETPR from the IDC model (ETPR-IDC) subtracted from total ET from OpenET (ET-OpenET). Although values differ across the participating lands, the representative overall ETAW value was equal to 10.8 IN. This value is 3.6 IN greater than the ETAW-IDC value of 7.2 IN (presented above), which represents a 33% or 50% increase over ETAW-IDC calculated relative to OpenET and IDC results, respectively. Although there is uncertainty in both datasets, these results indicate that the IDC model was underestimating total ET and ETAW.

Figure Error! Reference source not found.**3-5** depicts a cumulative timeseries plot presenting the a ggregated data for all participating lands (i.e., the 28 irrigation units described in **Section 3.1.2**) for five unique flow paths over the course of 2024. These overall results calculated by aggregating data are equivalent to area-weighted average depths for participating lands. The flow paths depicted include two for total ET (ET-IDC and ET-OpenET), one for ETPR (ETPR-IDC), and two for ETAW (ETAW-IDC and ETAW-OpenET)). This figure depicts the final values used as the representative overall values presented throughout **Sections 3.3.1 and 3.3.2**, and also shows how each flow path accumulated over the course of the 2024 Study period.

The ETPR results showed the most ETPR occurring during May and June; this is the period when the root zone was full from winter and spring P and ET demands were beginning to increase. When ETPR noticeably decreased during the month of July (due to most of P in the root zone being consumptively used as ETPR by this time), ETAW increased, due to growers increasing their AW. Based on field data and grower coordination, some growers in multiple crop categories did not begin irrigating until sometime in June, and some growers with vineyards did not begin irrigating until sometime in July. ETPR continued to accumulate each month during the Study period, including a final noticeable increase in accumulation rate (i.e., slope of line) in December, due to P late in 2024 and additional water available to support ETPR. The continued accumulation of ETPR modeled in IDC throughout the Study period indicates that some P remains in the root zone throughout the irrigation season in at least some participating lands to support ET demands.

As described above, the overall OpenET results tended to be higher than IDC and indicate potential underestimation of ET and ETAW by the IDC model. The cumulative line plots for OpenET and IDC for both ET and ETAW are relatively closely aligned until the end of June, after which they diverge, ultimately ending 3.6 IN apart by the end of 2024. During the months of June through September, OpenET accumulated at a higher rate than IDC, the two had relatively similar rates of accumulation during the month of October (the final month of irrigation season), and then IDC accumulated at a higher rate during November and December. Based on this, any potential refinements to IDC modeling of ET could focus on inputs and assumptions that would affect the summer and fall months where greater differences were observed. Additionally, for the aggregated results, it is worth noting that vineyards had a relatively larger impact on the cumulative timeseries plots due to both more overall participating lands being vineyards and vineyards having the largest average field size relative to other crop types (see **Table 3-2**).

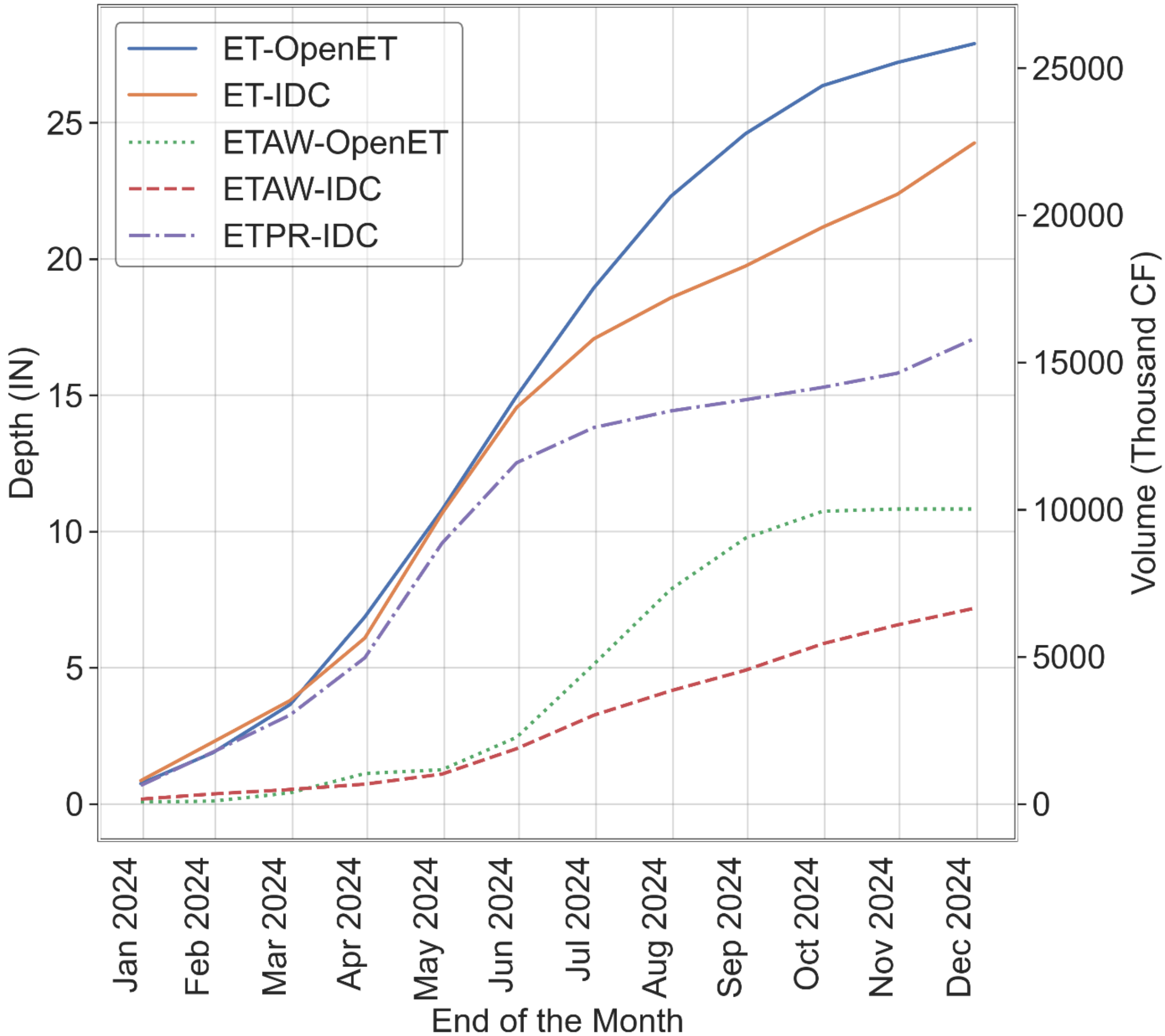


Figure 3-5. A cumulative line plot showing aggregated monthly results for five different flow paths in 2024 for 28 irrigation units: ET-OpenET, ET-IDC, ETAW-OpenET, ETAW-IDC, and ETPR-IDC. The total volume presented on righthand side of the y-axis is divided by total irrigated area to calculate the representative depth shown on the lefthand side of the y-axis.

3.3.3 Consumptive Use Fraction (CUF) (referred to as Irrigation Efficiency in 2020 Report)

As described in **Section 2.3.3**, the CUF (or irrigation efficiency, as described in 2020 Report) was assumed or calculated using four separate methods. The results for these are described in the sections below.

There is limited outside information presenting expected values, or even ranges of expected values, for a CUF for irrigated agriculture due its variability depending on a wide variety of local conditions. Factors influencing the CUF include crop type, irrigation method, water availability (both precipitation and applied water), grower practices, and in-field conditions. A literature review was completed to evaluate expected values for CUF, or related metrics used to evaluate the application of irrigation water for agricultural production. The results of this review are presented below.

Irrigation efficiency (IE) is defined as the ratio of the volume of irrigation water beneficially used to the volume of irrigation water applied (i.e., volume beneficially used / volume applied) (ASAE, 1990). It is very similar to the CUF (and was used in the 2020 Report to describe the CUF). The minor difference is that the CUF only compares volume consumptively used to volume applied. Consumptive use represents the large majority of applied water for all irrigated crops, but there are some minor uses that are non-consumptive. These include leaching of salts, frost protection, and application of pesticides or fertilizers (which require dilution with water before application). Based on grower coordination, salt leaching was not practiced on any participating lands, but water use associated with frost protection and application of pesticides and fertilizers occurred on some participating lands. The volumes associated with these practices is minimal, but to the extent it occurred, an irrigation unit would have a slightly higher IE than CUF value due to these non-consumptive beneficial uses of applied water. An online source from the University of Nebraska-Lincoln (UNL) included expected ranges of values for IE based on the type of irrigation system. Average values were calculated for flood (e.g., furrow) and pressurized (e.g., sprinkler, drip) irrigation systems; these values were 0.63 and 0.80, respectively (UNL, 2019).

Application efficiency (AE) is synonymous with DU; it describes how evenly water for irrigation is applied across an area. A book published by the American Society of Agricultural Engineers (ASAE) provided a range of expected values for AE dependent on irrigation system type; the average values from these ranged from 0.66, 0.73 and 0.74 for surface, sprinkler, and drip or micro, respectively (ASAE, 1990). The Center for Irrigation Technology (CIT) at Fresno State University also completed a literature review that compiled typical ranges for AE, dependent on irrigation system type, from six other sources. The information in this review was used to extract average values for flood and pressurized irrigation systems, with resulting values of 0.72 and 0.85, respectively (CIT, 2011).

One important factor influencing IE, AE, and CUF is topography. Elevation changes over an irrigated area, which are common for irrigated fields in El Dorado County and present across participating fields, often will reduce these values. For flood or surface irrigation "*nonuniform surface elevation is the main reason for nonuniform water distribution*" and for sprinkler irrigation systems, elevation changes "*can reduce the field DU [or AE] by 10 to 20%*" (ASCE, 2016). Elevation changes in pressurized irrigation systems cause pressure variability, which impacts emitter or sprinkler discharge (for non-pressure compensating emitters or sprinklers). Other sources also acknowledge the impact of elevation changes on applied water for irrigation (UCCE, 1981; ASAE, 1983; ASAE, 1990). All else being equal, IE, AE, and CUF values for a foothill area such as EDC would be expected to be lower than in a flat area such as the Central Valley due to topographic changes.

As another point of comparison, a similar dataset to the one prepared for the Study was also referenced. This dataset compares applied water for irrigation of agriculture measured through flowmeters to ETAW from a variety of remote sensing products (including OpenET) to calculate CUF values, and it was collected and assembled in Madera County during 2023 (MCDWNR, 2024). The results showed CUF values ranging from 0.85 to 0.90 based on an aggregated data analysis and 0.77 to 0.80 based on a regression analysis for the same dataset (MCDWNR, 2024). The regression analysis values generally align with the upper end of the range of average values obtained for IE and AE from the literature review, while the aggregated data analysis values are higher. These higher CUF results from Madera County may be influenced by water scarcity, the practice of deficit irrigation, and careful management of available groundwater supplies under the Sustainable Groundwater Management Act (SGMA) and by more uniform soil types and the relatively flat topography on the San Joaquin Valley floor.

Overall, these values provide another point of comparison to the CUF values measured, calculated, and compiled as part of the Study and presented below and show that typically expected values for CUF range from around 0.60 to 0.90 for less efficient applications of AW to more efficient applications

3.3.3.1 CUF assumed to be 0.8 (CUF-0.8)

As described in **Section 2.3.3.1**, the CUF in the 2020 Report was assumed to be equal to 0.80 for all crops, irrigation methods, and other conditions and characteristics (practically meaning that 80% of AW results in ETAW) (CUF-0.8). This assumed value is referenced in comparison to the CUF values calculated and presented subsequently.

3.3.3.2 CUF Based on ETAW-IDC and AW-WM (CUF-IDC)

As part of the Study and subsequently described in **Section 3.3.4**, measurements of AW were collected from water meters during the 2024 irrigation season (AW-WM). The representative overall ETAW-IDC value for 2024 extracted from the IDC model (see **Section 3.3.2.3**) was divided by the representative overall AW-WM value to calculate a CUF value of 0.52 (CUF-IDC). These representative overall values, expressed in inches (IN), were determined by summing the total volume for participating lands (i.e., the 28 irrigation units described in **Section 3.1.2**) and dividing by the total irrigated acreage of participating lands to calculate a representative area-weighted average depth (see **Figure 3-6** below). Aggregating the total volumes and irrigated areas together to calculate a representative overall CUF inherently gave greater weight to the larger irrigation units.

CUF-IDC equal to 0.52 was substantially lower than the 0.80 value assumed in the 2020 Report and also below the 0.60 to 0.90 range of expected CUF values. As noted in **Section 3.3.2.4**, the IDC model underestimated ET and ETAW, which impacted this calculation of CUF. If the ETAW value in the numerator is increased, the CUF value will also increase. In order to quantitatively evaluate how changes to ETAW values impacted the CUF calculated with AW-WM held constant in the denominator, the next section calculates CUF using ETAW values based on OpenET data.

3.3.3.3 CUF Based on ETAW-OpenET and Observed AW (CUF-OpenET)

As subsequently described in **Section 3.3.4**, measurements of AW (AW-WM) were collected and are available for CUF calculations. The representative overall ETAW-OpenET value (see **Section 3.3.2.4**) was divided by the representative overall AW-WM value to calculate a CUF value of 0.78 (CUF-OpenET). The methodology for determining these representative overall values and utilizing them to calculate the CUF was described in the previous section. Regarding the results, ETAW-OpenET was noticeably higher than ETAW-IDC, causing in this noticeably higher CUF-OpenET value. The value of 0.78 is very close to the 0.80 value assumed in the 2020 Report (the 0.80 value is 3% higher), and it is also within the 0.60 to 0.90 range of expected CUF values.

Figure 3-6 depicts a cumulative timeseries plot presenting the aggregated data for all participating lands (i.e., the 28 irrigation units described in **Section 3.1.2**) for six unique flow paths over the course of 2024.

These overall results calculated by aggregating data are equivalent to area-weighted average depths for participating lands. The flow paths depicted are two for ETAW (ETAW-IDC and ETAW-OpenET) and four for AW (AW-IDC, AW-OpenET, AW-OpenET-CUF-DU, and AW-WM). The AW flow paths are described subsequently in **Section 3.3.4**, but the results are shown here in order to provide more information about calculations of different CUF values based on different datasets and results.

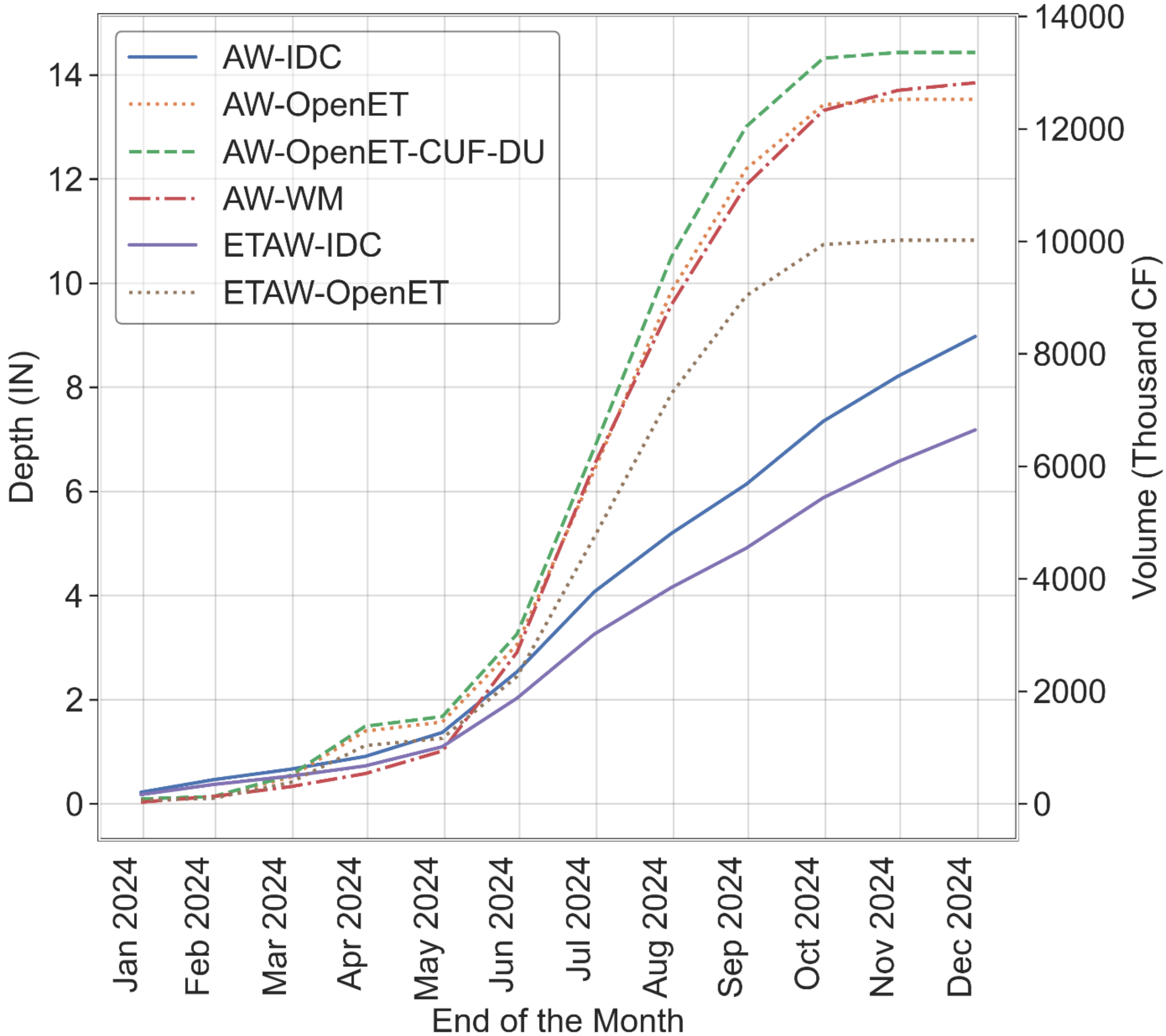


Figure 3-6. A cumulative line plot showing aggregated monthly results for six different flow paths in 2024 for 28 irrigation units: ETAW-IDC, ETAW-OpenET, AW-IDC, AW-OpenET, AW-OpenET-CUF-DU, and AW-WM. The total volume presented on righthand side of the y-axis is divided by total irrigated area to calculate the representative depth shown on the lefthand side of the y-axis.

The trends show results over the course of the 2024 calendar year (including steeper rates of accumulation during the irrigation season from June through October). Most notably for discussion related to the CUF though are the final end-of-year values for ETAW and AW. The total volume (shown along the righthand side of y-axis) is divided by the irrigated area to calculate a representative depth for each flow path (shown along the lefthand side of the y-axis). Aggregated AW-WM for the Study Period was 13.8 IN; when the aggregated ETAW-IDC of 7.2 IN was divided by AW-WM it resulted in a CUF of 0.52 (CUF-IDC, a lower than expected value). When the aggregated ETAW-OpenET value of 10.8 IN was divided by AW-WM it resulted in a CUF of 0.78 (CUF-OpenET, within the range of expected values).

3.3.3.4 CUF Upper Limit from Distribution Uniformity (DU) Testing (CUF-DU)

As described in **Section 2.3.3.4**, DU testing was also completed and results can be used as an upper limit of potential CUF values. There were a total of 33 DU tests performed during data collection over the course of the 2024 irrigation season. The distribution of values is shown in a histogram below in **Figure 3-7**. The median DU value was 75%, or 0.75 (CUF-DU). The half of the DU values in the middle of the distribution ranged from 56% to 82%, and one quarter of the DU values were lower than 56% and higher than 82%, respectively. Because DU establishes the upper limit of the CUF, the median DU value of 0.75 suggests that the average CUF should be less than 0.75 (assuming deficit irrigation is not occurring). As presented above, the CUF-IDC was substantially lower than 0.75, and the CUF-OpenET was slightly. Neither of these values align with the expectation of a CUF slightly lower than the DU values, but although the CUF-OpenET equal to 0.78 is only 0.03 higher (a 4% difference relative to CUF-DU).

As expected when collecting data in the field, there was a lot of variability in results from DU testing. Two DU results were above 90%, indicating excellent DU. On the opposite side, four were less than 50%, indicating very poor DU. The majority of DU percentages were between these two extremes.

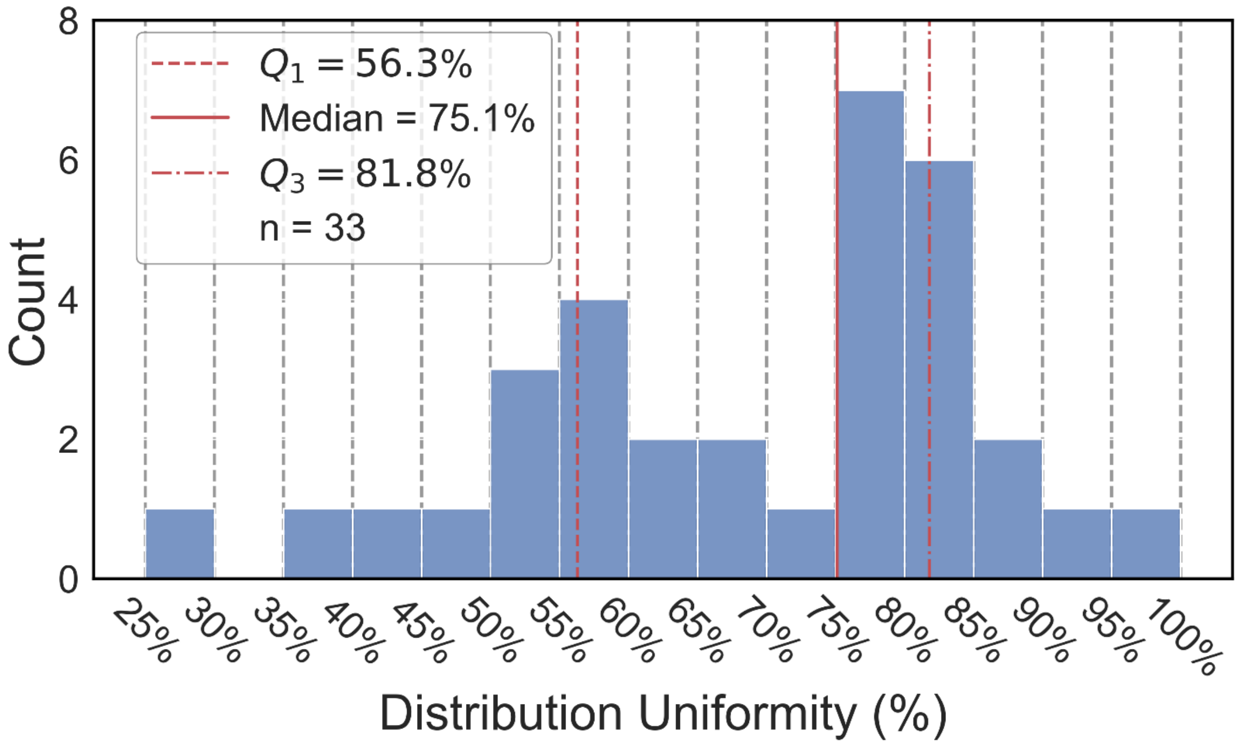


Figure 3-7. Histogram depicting the results of DU testing. Values above 90% are considered excellent, 80% to 90% are good, 60% to 80% are fair, and below 60% are poor. The median value was 75%, and the half of the DU values in the middle of the distribution ranged from 56% to 82%.

As part of the 2020 Report, 75th percentile crop coefficients (based on the 2017 METRIC analysis) were utilized for estimating AW requirements for planned irrigated agricultural growth, along with the assumed CUF value of 0.80. The DU testing showed an increase from 0.75 to 0.82 (a 9% difference relative to median) between the median and 75th percentile values of DU. This 0.82 value is close to, but slightly higher than, the CUF-OpenET (0.78) and CUF-0.8 (0.80). Since DU typically establishes the upper limit for the CUF, this DU value aligns well with these two other CUF values.

One factor that has a big impact on DU is the irrigation method. The participating lands included in the Study were irrigated using three different methods: drip, micro-sprinkler, and overhead sprinkler irrigation systems. DU tests were performed on fields using all three of these methods, with 14, 9, and 10 tests for drip, micro-sprinkler, and overhead sprinkler irrigation systems, respectively. The results presented above include aggregated results for all methods, while the three boxplots below in **Figure 3-8** show the distribution of DU results for each irrigation method.

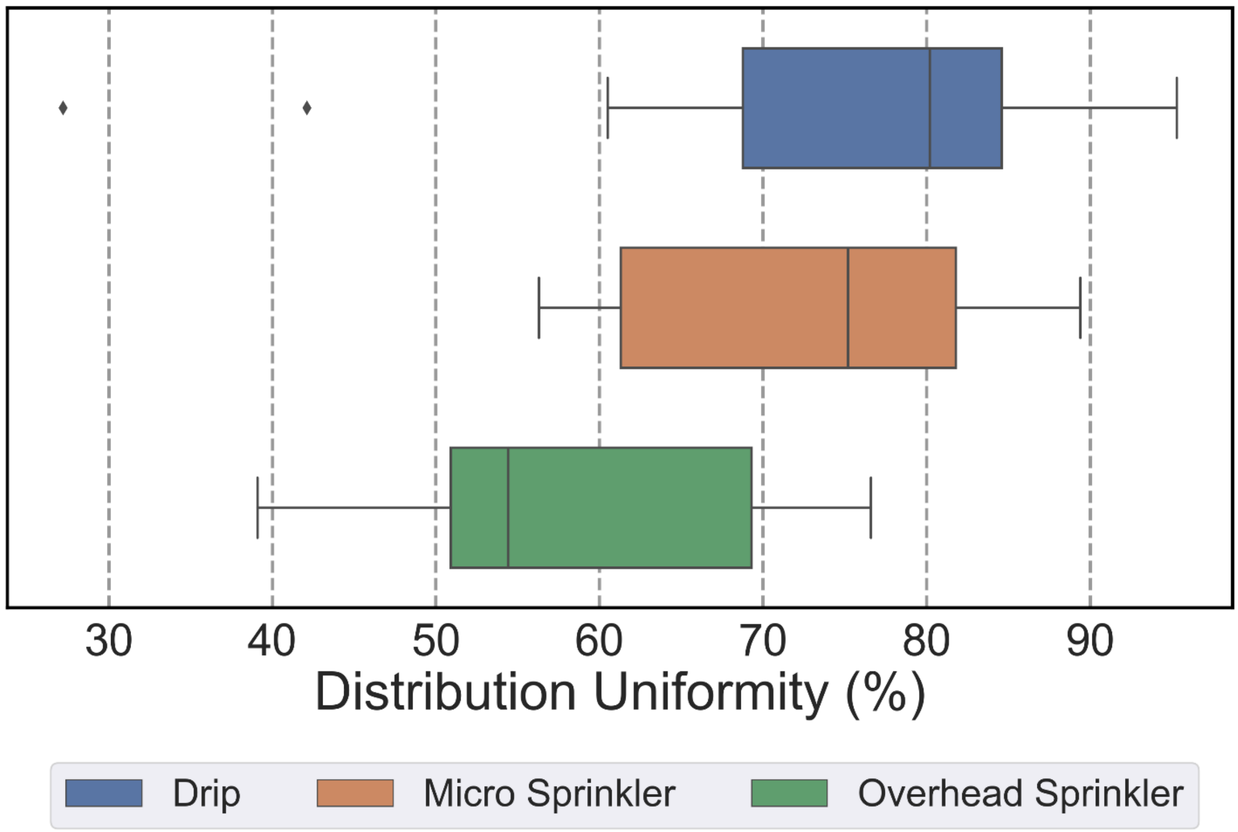


Figure 3-8. Boxplots showing distribution of Distribution Uniformity (DU) testing results for each of the three irrigation methods (drip, micro-sprinkler, and overhead sprinkler) included in participating lands in the Study.

The results by irrigation method generally aligned with expectations. As the uniformity of irrigation application decreases from drip to micro-sprinkler to overhead sprinkler, the DU values tended to decrease as well. The median values for each method were approximately 80%, 75%, and 54% for drip, micro-sprinkler, and overhead sprinkler, respectively. It is worth noting that two of the lowest DU results (with the lowest being less than 30%) were for drip irrigation systems. The irrigation block for this lowest value was on a substantial slope with large elevation differences, which resulted in large system pressure and drip emitter discharge variability and low DU, and the irrigation system was noted to be in disrepair with many holes and breaks in drip lines observed during testing.

An evaluation of 16 irrigation systems was completed in El Dorado County during the 1979 and 1980 irrigation seasons that included DU testing. The primary irrigation method at this time was overhead sprinklers; drip irrigation was an emerging technology. The DU results ranged from 46% to 85% with a median value of 73% (UCCE, 1981). This median value is slightly lower than but close to the 75% median value observed from DU testing for the Study. The increase in median DU, along with the increase in maximum DU values from 85% to over 90% between the two studies, may be reflective of increasing DU over time in EDC.

As discussed in **Section 2.3.3.4**, DU can represent an upper limit of potential CUF values. Although the DU results show variability across the irrigation systems for participating lands (and notable differences between irrigation methods), the values generally aligned with expected values and trends. The overall median value of 0.75 across all tests was within the range of expected values for the CUF and for DU (or AE) of these irrigation systems. Also, the 75th percentile value of 0.82 aligned well with the slightly lower values of CUF-OpenET (0.78) and CUF-0.8 (0.80) under the expectation of CUF being slightly lower than DU.

3.3.4 Applied Water

3.3.4.1 AW Based on ETAW-IDC (AW-IDC)

As described in **Section 2.3.4.1**, applied water was calculated based on the methodology from the 2020 Report as the ETAW extracted from the IDC model for the 2024 calendar year divided by an assumed consumptive use fraction (CUF), or irrigation efficiency, of 0.80 (or 80%). The ETAW (and thus AW) values are variable across the participating lands due to differences in geographic location, soils, and crop type, but when the results were combined to calculate a representative overall AW value, the result for the 2024 Study period was 9.0 IN. Crop-specific values for the four major crops included in the Study were also calculated and are directly compared to water meter measurement results in the next section.

3.3.4.2 Applied Water Measured with Water Meters (AW-WM)

The applied water measured as part of this Study was directly recorded in the field from water meter readings (or provided by EID), and the results from the 2020 Report and this Study can be directly compared. These data are depicted in **Figure 3-9** (which includes the same format and same irrigation units as **Figure 3-4**); the results from the 2020 Report appear as a single average value (the dashed line) and the distribution of applied water measured by water meters (AW-WM) for all irrigation units for a crop type are shown as a boxplot.

The applied water values observed from water meters tended to be higher than those modeled as part of the 2020 Report. For apples, all values measured by water meters are higher. For the other three crops (Christmas trees, miscellaneous deciduous, and vineyards), the majority of values measured by water meters were higher. The median values (i.e., the line in the middle of each box plot) from water meters for all four crops were higher than the average value from the IDC model, and the difference between the median and average for apples and vineyards was noticeably larger than for Christmas trees and miscellaneous deciduous. A broader range of measured AW values was also observed for both miscellaneous deciduous and vineyards, relative to Christmas trees and apples. For both miscellaneous deciduous and vineyards, the lowest AW depths were roughly 5 IN and the highest were roughly 30 IN (a roughly 25 IN range), while Christmas trees and apples showed a low to high range of less than 10 IN. Note that the miscellaneous deciduous category also includes irrigation units with mixed cropping. Overall, these results indicate that the modeling approach from the 2020 Report was underestimating applied water for all of the major crop types to some degree.

There is uncertainty associated with each of these approaches to quantifying applied water. For the modeling approach in the 2020 Report, an important assumption impacting the results was the CUF value of 0.80, which was acknowledged to be potentially higher than actual CUF values. Decreasing this assumed CUF value would increase the calculated applied water through the approach taken in the 2020 Report, reducing the differences currently observed between the 2020 Report and this Study or even potentially causing modeled results to exceed measured results from water meters. The CUF was also independently evaluated as a metric in **Section 3.3.3**.

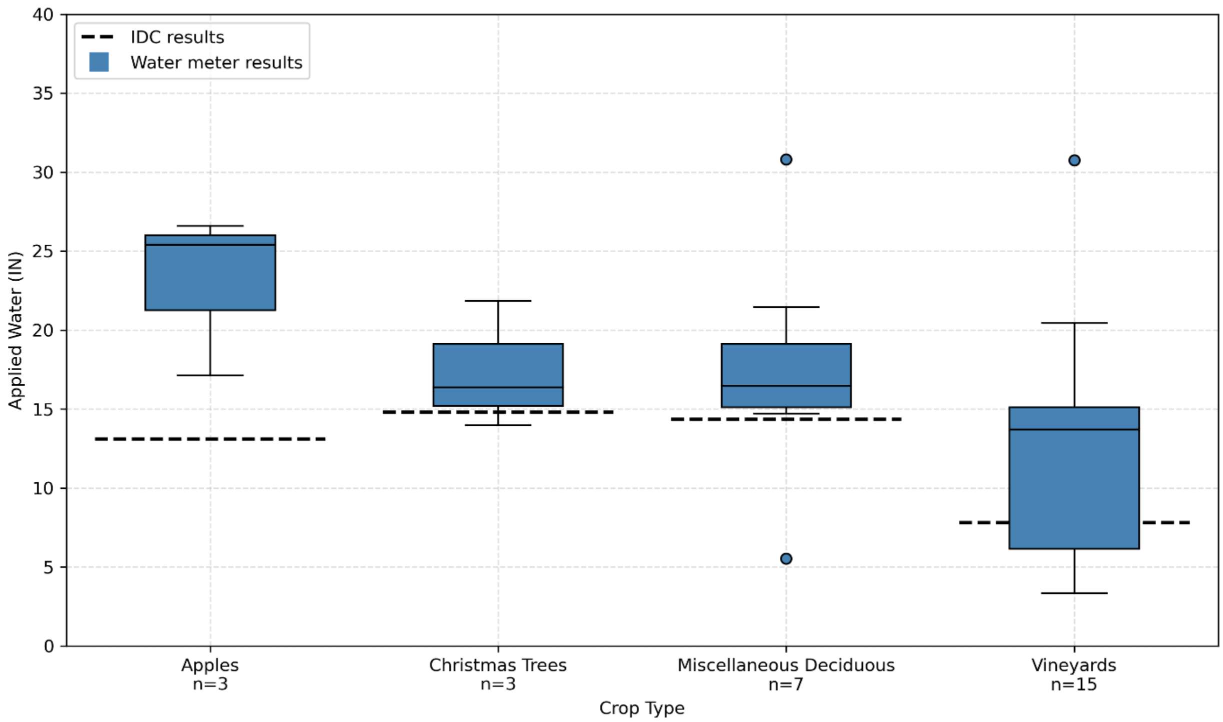


Figure 3-5. Comparison of applied water data from water meters (AW-WM, boxplots) to average results from the 2020 Report (AW-IDC, dashed line) for the four major crops with participating lands in 2024. The irrigation unit sample size for each crop type is shown along the x-axis. Note that mixed crop irrigation units are classified under miscellaneous deciduous.

For the applied water meters, one source of uncertainty for some irrigation units was the estimation of water volumes for purposes other than the irrigation of agriculture; the estimation of these is summarized in **Appendix C**. The estimated volumes for other purposes were substantially smaller than water volumes for irrigation of agriculture, so the impact of this uncertainty was relatively small**.** Lastly, a final source of uncertainty was the accuracy of water meters for measuring flow and totalizing a volume that has flowed through the meter over time. In order to evaluate this, independent flow measurements were performed for comparison to the water meter. These are described in **Section 3.3.4.5.** In general, the applied water values measured by water meters are expected to be more accurate than the applied water values estimated through IDC modeling in the 2020 Report. These measured applied water values should be used to evaluate and potentially refine assumptions and approaches in the 2020 Report for the calculation of estimated applied water requirements.

While the figure above shows annual values for 2024, **Figure 3-10** below depicts a monthly timeseries of 2024 data for average measured AW in each of the four major crop categories included in the Study. It can be observed from this figure that the months with highest applied water were June, July, and August for all crop types. The applied water for apples is noticeably higher than applied water for the other three crop types.

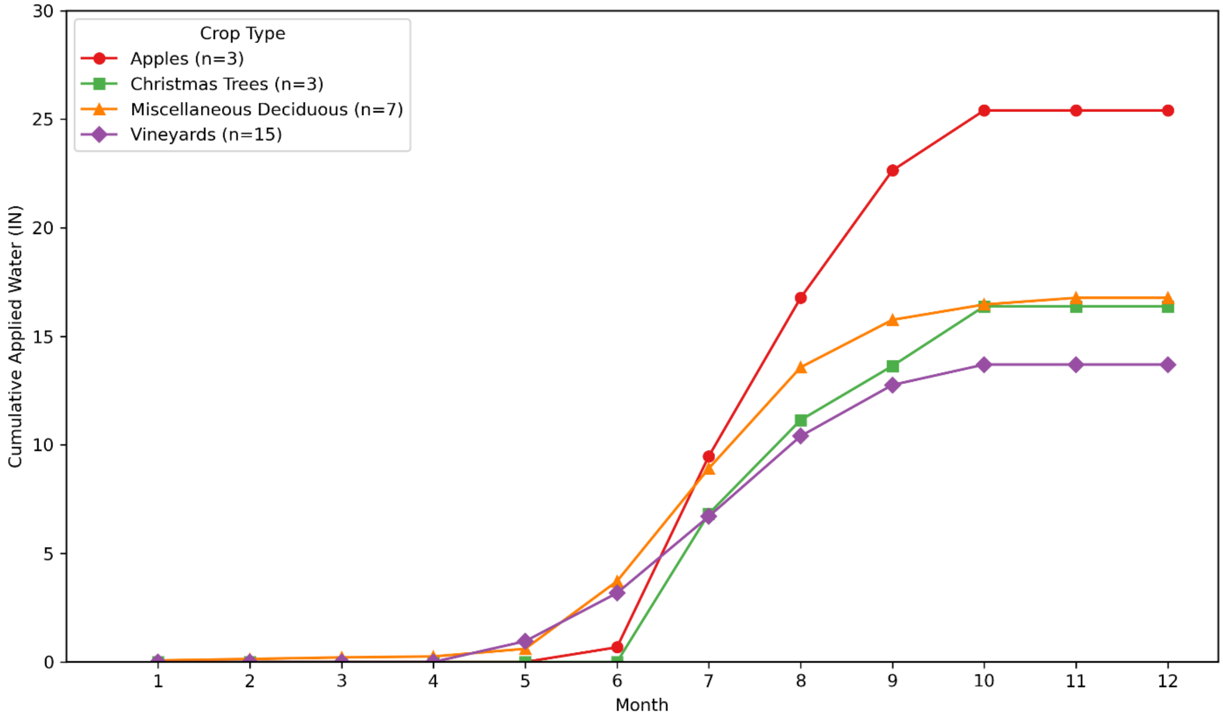


Figure 3-6. A cumulative line plot showing average monthly measured applied water (AW) in 2024 for the four major crops with participating lands in the Study. The vertical marker for each month represents the end of the month.

Finally, during field visits to collect data for applied water, if irrigation was actively occurring, visual observations were made to see if any tailwater was occurring (i.e., active flow of water across the ground surface and away from the field being irrigated). Although there is potential that tailwater may have occurred during times of irrigation between the periodic field visits, there were no visual observations of tailwater flowing off the low ends of irrigated fields during data collection. Additionally, there was no observable evidence that tailwater flowed from irrigated fields at other times.

For the data measured through water meters (AW-WM), when the results were combined to calculate a representative overall AW value, the result for the 2024 Study period was 13.8 IN. This value was substantially higher than the 9.0 IN for AW-IDC, and some other assumptions and calculations were made to complete other AW calculations for comparison and evaluation, as presented below.

3.3.4.3 AW Based on ETAW-OpenET (AW-OpenET)

As described in **Section 2.3.4.3**, the representative overall value for ETAW from OpenET (ETAW-OpenET) was divided by the assumed CUF value of 0.80 (CUF-0.8) to calculate estimated applied water (AW-OpenET) based on OpenET data instead of IDC model results. This resulted in a value of was 13.5 IN for participating lands and the 2024 Study period. This value was substantially closer to the AW-WM value than the AW-IDC value was, with the 0.3 IN difference being 2% lower relative to AW-WM.

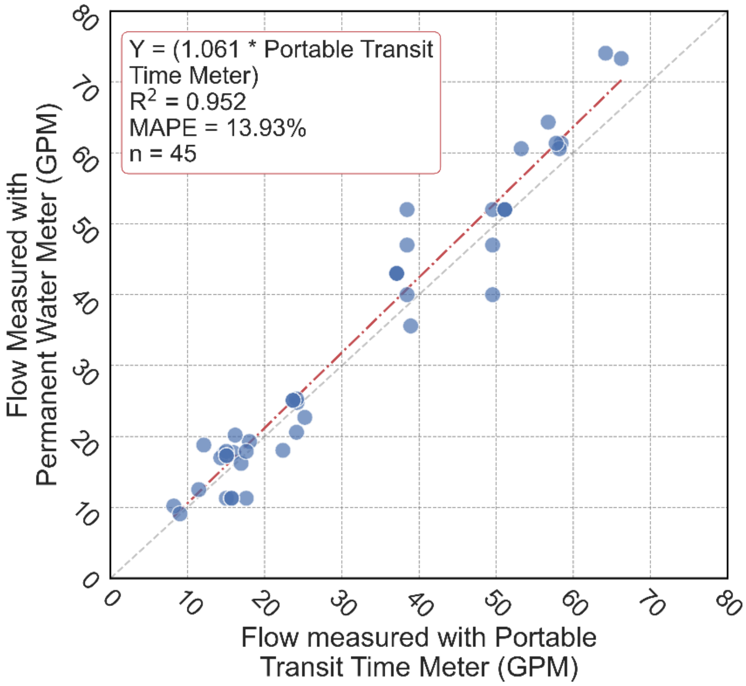
3.3.4.4 AW Based on ETAW-OpenET and CUF-DU (AW-OpenET-CUF-DU)

As described in **Section 2.3.4.4**, AW was calculated one additional way for comparison, once again using ETAW-OpenET as the initial starting point. However, to evaluate how a different, lower CUF value would impact estimated AW requirements, the median value of 0.75 from DU testing was utilized as the assumed CUF (CUF-DU) to convert from ETAW to AW (AW-OpenET-CUF-DU) by dividing the ETAW by the CUF. This calculation resulted in a representative overall value of 14.4 IN, which exceeded the AW-WM by 0.6 IN (4% higher relative to AW-WM).

3.3.4.5 Water Meter Comparison Flow Measurements

As described in **Section 2.3.4.5**, the flow rate was recorded whenever field visits to read water meters coincided with active irrigation and water flowing through the water meter while staff were on site. If the piping configuration allowed, an independent flow measured using a portable transit time flowmeter was also completed (with the goal of at least one flow measurement per site, although some sites did not have flow measurements completed while others had multiple flow measurements). The results of these comparison flow measurements are shown below in **Figure 3-11,** with both a scatterplot comparing flows and a histogram comparing differences between the flow measurements.

In total, 45 comparison measurements were performed; each is shown as a point on the scatterplot. The 1:1 line is shown as a gray line; any points that fall on this line indicate perfect agreement between the portable transit time meter and the water meter. The regression analysis to determine line of best fit shows results in a slope (b) equal to 1.06, meaning that based on the dataset, water meters tend to be 6% higher than the portable transit time meter (see red dashed line). Based on this slope, for a measured flow of 25 GPM with the portable transit time meter, the permanent water meter flow would be equal to 26.5 GPM. The coefficient of determination (R^2) is a measure of how closely the regression line fits the data in the scatterplot (with a value closer to 1 being indicative of a better fit), and the R^2 is close to one with a value of 0.95.



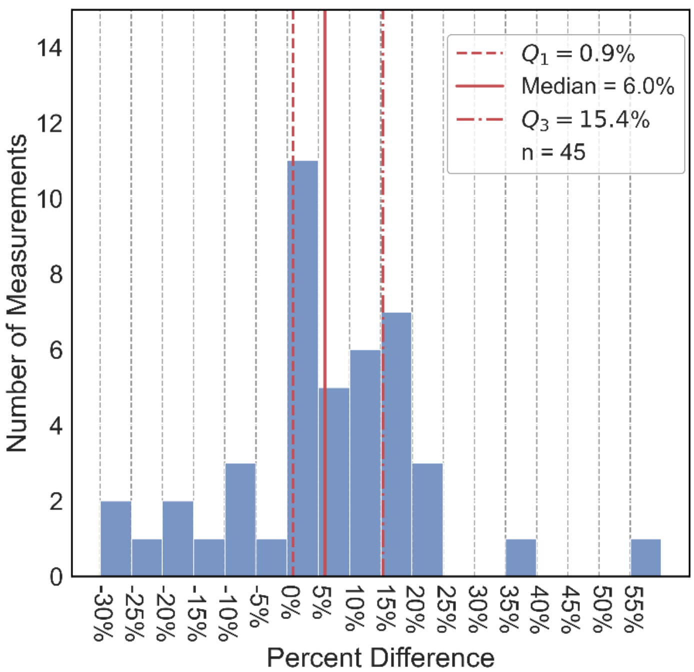


Figure 3-7. Scatterplot comparing flow measurements with portable transit time flowmeter to permanent water meters (top) and histogram comparing differences between the two measurements (bottom).

The histogram analysis showed a median difference of 6.0% (equal to the 6% difference from regression analysis) between the two measurement devices (with the water meter having higher flow). For over 75% of the total comparisons, the water meter measured a higher flow than the portable transit time meter, while the remaining comparisons showed the water meter measuring a lower flow.

It is worth noting that water meters (regardless of make and model) may malfunction and measure inaccurately[24], or be installed in locations where measurement conditions are not ideal, so there is uncertainty associated with water meter measurements. Similarly, the portable transit time meter requires certain upstream and downstream lengths of pipeline without disturbances to flow for ideal measurement conditions. In most cases, these conditions were not available and measurement location was dictated by where there was enough exposed pipeline to install the meter and complete a measurement. Due to this, there was a higher uncertainty in the flow measurements with the portable transit time meter than the uncertainties specified by the manufacturer based on equipment accuracy and measurement technology. Although neither flow measurement was expected to be completely accurate, the relatively close alignment between the two datasets indicated that the water meters observed over the course of the Study measure flow rates and cumulative water volumes with reasonable accuracy.

3.3.5 Historical Data Analysis

As described in **Section 2.3.5**, available historical data were compiled for participating lands in the Study and evaluated to assess annual variability and how 2024 compared to average conditions over time. The primary limiting factor from a data availability standpoint was applied water data through water meters. Historical applied water data were only available through the water meter records provided by EID; these records went back as far as 2006, but were sometimes limited to more recent years due to property ownership changes or influenced by water meter failure/replacement that impacted the data record. The objective of comparing 2024 to average conditions over time was to evaluate how representative 2024 was of long-term average conditions.

The number of irrigation units with available historical applied water data increased gradually from 11 to 14 between 2006 and 2024 (a 19-year period), as shown in **Figure 3-12**. Roughly half of the irrigation units included were vineyards, while the other half were miscellaneous deciduous, Christmas trees, or mixed cropping (and an apple irrigation unit beginning in 2019). In order to have a consistent dataset for comparison of trends and differences over time, only the data from the 11 irrigation units with applied water data for the full period between 2006 and 2024 were considered in the assessment and comparison presented below for AW, ET, and P. Also, land use or other changes on these irrigation units and properties during this period were not evaluated. The impacts of any changes on applied water records for these properties are inherently included in these results presented and discussed, but the specific causes (e.g., removal of irrigated crops, addition of irrigated crops, water demands for permanent crops changing as they mature over time) and estimated impacts on applied water have not been researched or quantified. Lastly, the results depicted below for 2024 will differ from those presented in **Section 3.1.2** because only a limited amount of the overall participating lands had historical applied water, and therefore these results only represent this smaller subset of participating lands in the Study.

[24] Additionally, when water meters malfunction they tend to record lower than actual volumes, although this general trend is dependent on technology used to measure water velocity, flow, and volume for each meter. For mechanical meters (such as propeller meters), which are common, water velocity is measured based on how quickly parts rotate (with rotation rate increasing based on increasing water velocity). If mechanical meters malfunction, they often rotate more slowly, thus recording lower than actual volumes.

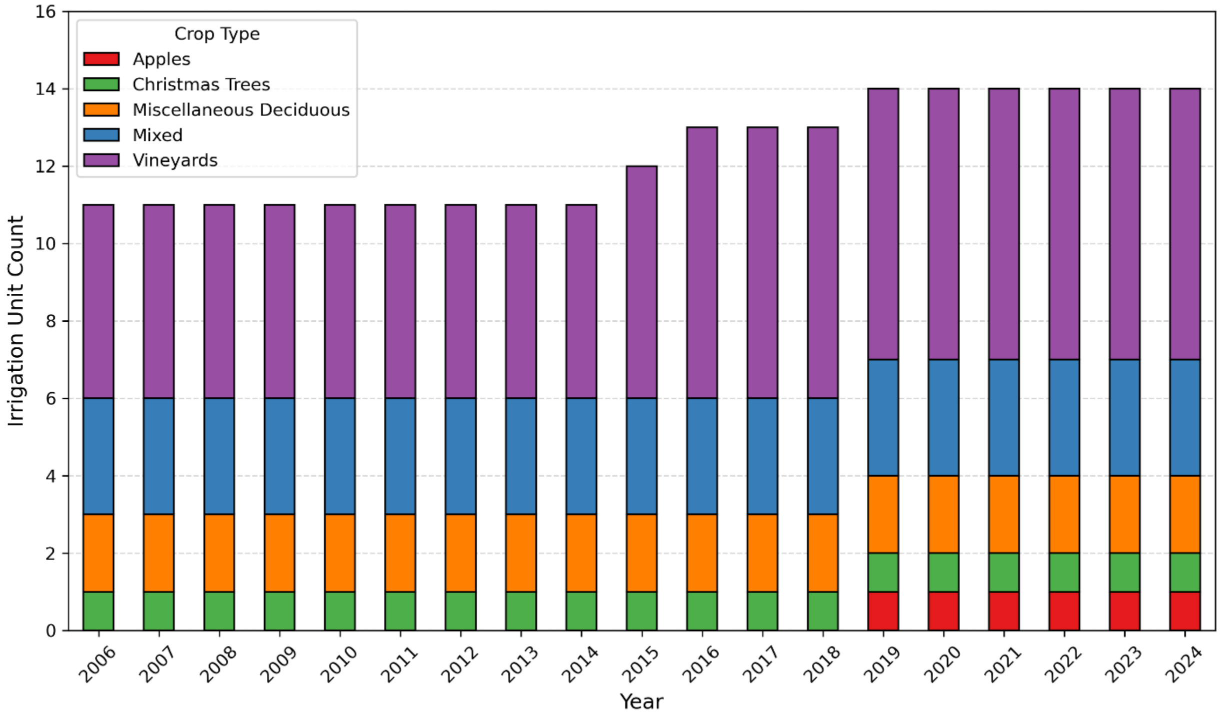


Figure 3-12. A stacked bar chart showing the number of irrigation units, colored by crop type, with historical applied water data during the period from 2006 to 2024. These applied water data were based on historical EID water meter records.

For the 11 irrigation units with data from 2006 through 2024, the total annual water volumes were calculated (including any adjustments for water used for other purposes, see **Appendix C**), aggregated together, and divided by the total irrigated area to determine a representative depth of applied water for each year. The results for this are shown in **Figure 3-13**. The average annual AW over the historical period ranged from 10.4 to 20.8 IN, with an overall average of 14.6 IN. The AW in 2024 of 19.1 IN was the second-highest value between 2006 and 2024 and was noticeably higher than prior years. These results were likely influenced by a combination of factors, but some potential factors include higher overall ET demands and a longer irrigation season, relative to prior years. The 2024 AW of 19.1 IN is also 5.3 IN higher than the AW-WM results for all participating lands of 13.8 IN (a 38% increase relative to AW for all participating lands). This substantial increase was also likely influenced by a combination of factors, but two potential factors may be higher crop water demands on these 11 irrigation units relative to others in the Study and increased water availability within the EID service area. Most irrigated lands outside of water purveyor boundaries (e.g., EID) in EDC are dependent on groundwater for irrigation and have wells with limited production capacity, resulting in relatively lower overall AW for those lands.

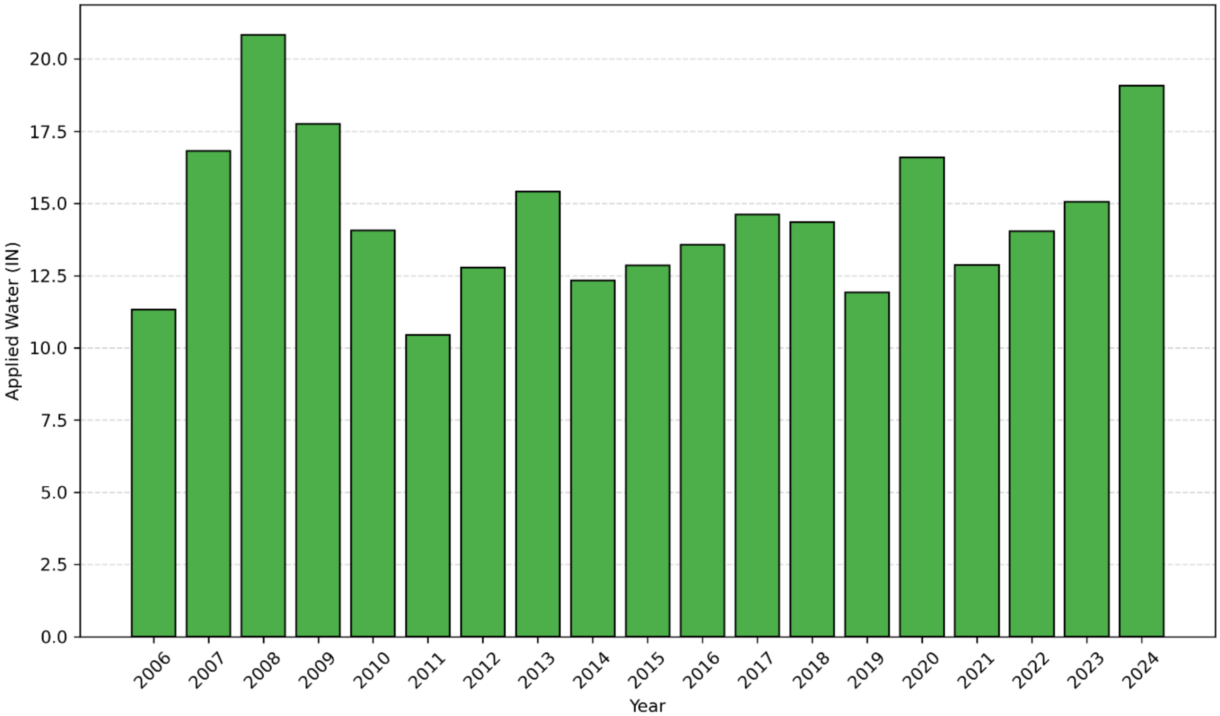


Figure 3-13. A bar chart depicting average annual applied water for 11 irrigation units with available data throughout the 2006 to 2024 period. Area-weighted average applied water depths ranged from 10.4 to 20.8 IN with an overall average of 14.6 IN.

The other source of water for irrigated lands in EDC is precipitation (P), which was evaluated along with inclusion of the hydrologic year type from the Sacramento Valley Water Year Index (SVWYI). The SVWYI is based on measured unimpaired runoff for the Sacramento River watershed[25] and includes annual water year classifications as wet (W), above-normal (AN), below-normal (BN), dry (D), or critical (C). The American River is a tributary to the Sacramento River (i.e., within the Sacramento River watershed), and the American River watershed covers the majority of the West Slope of EDC (roughly 67%). **Figure 3-14** depicts P over the 19-year period from 2006 to 2024 for the 11 irrigation units, along with a notation of hydrologic year type based on the SVWYI. P ranged from a low of approximately 12.6 IN (2013, D) to a peak of 63.1 IN (2017, W) with an overall average of 39.6 IN. Based on the SVWYI, five (26%) of the years were classified as C, four (21%) as D, four (21%) as BN, one (5%) as AN, and five (26%) as W. Although precipitation levels generally follow the SVWYI, there are some notable exceptions. Multiple BN years (2010, 2012, and 2016) had higher precipitation than some AN and W years, indicating that relatively more precipitation occurred on these 11 irrigation units than across the remainder of the Sacramento Valley watershed[26]. Overall, the results demonstrate the high variability of P over time in EDC. As described earlier, although it is dependent on the timing and extent of P, P and AW are generally inversely correlated. The higher P is, the more water from P will be available to support crop water demands, and the less AW will be required, and vice versa. The P in 2024 was 42.0 IN, which was 2.4 IN

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[25] More information about the Sacramento Valley Water Year Index, including historical values, can be found at: https://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST

[26] It is also worth noting the P was aggregated for the calendar year (January 1st through December 31st) for this Study, while the SVWYI aggregates P for the water year (October 1st through September 30th). This was also a factor in differences observed.

higher than the average of 39.6 IN (6% higher relative to the average). Thus, 2024 had levels of P fairly close to average annual levels.

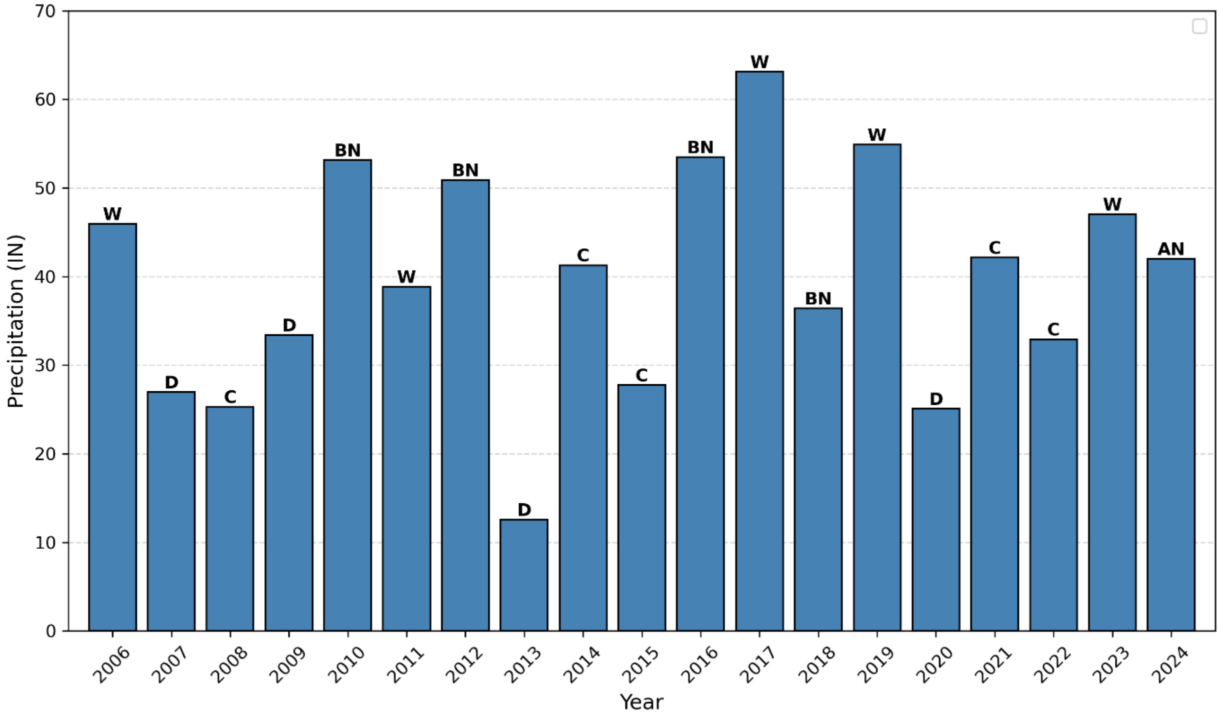

Figure 3-14. A bar chart depicting average annual precipitation from 2006 to 2024 along with the classification of hydrologic year type for 11 irrigation units. The hydrologic year type is based on the Sacramento Valley Water Year Index with classifications as wet (W), above-normal (AN), below-normal (BN), dry (D), or critical (C). Area-weighted average precipitation depths ranged from 12.6 to 63.1 IN with an overall average of 39.6 IN.

Historical ET was also collected and evaluated for the 11 irrigation units. In comparison to AW and P, ET remained relatively consistent between 2006 and 2024. P ranged from a low of approximately 23.3 IN to a peak of 29.8 IN with an overall average of 26.9 IN. The relative consistency of ET across this period indicates that it was not likely that any major shifts in cropping or water demands during this 19-year period occurred for these 11 irrigation units. The combination of P and AW are used to meet crop ET demands, and although ET demands remain relatively consistent, the P and AW can vary widely between years. AW is required to meet ET demands that are not met by P. The ET in 2024 was 29.5 IN, which was 2.6 IN higher than the average of 26.9 IN (10% higher relative to the average). The higher ET in 2024 was likely influenced by a combination of factors, but some important potential ones include weather parameters affecting ET such as higher temperatures, more solar radiation, and an increased number of windy days. Prolonged periods with higher temperatures in particular were noted by participating growers during data collection and grower coordination during the 2024 irrigation season. The 2024 ET of 29.5 IN was also 2.0 IN higher than the ET-OpenET results for all participating lands of 27.5 IN (a 7% increase relative to ET for all participating lands).

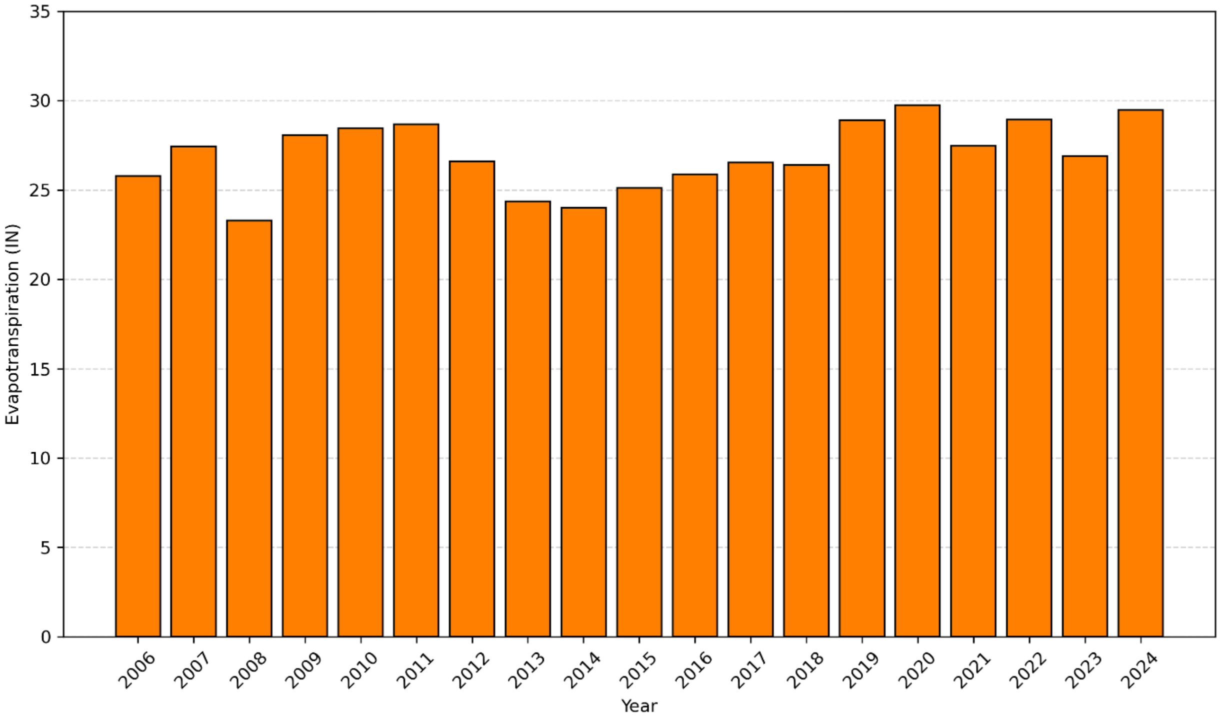

Figure 3-15. A bar chart depicting average annual ET from 2006 to 2024 along with the classification of hydrologic year type for 11 irrigation units. Area-weighted average ET depths ranged from 23.3 to 29.8 IN with an overall average of 26.9 IN.

The annual AW, P, and ET values presented in this section were also combined together into one plot to allow for easier comparison and observations in **Figure 3-16.** This figure also depicts the scale of each flow path relative to other flow paths, with P typically being the largest (except during dry periods), followed by ET, and then AW (which was always the smallest). As described in this section, the values in 2024 for all three flow paths were above average relative to average values for the 19-year period between 2006 and 2024. The inverse relationship between AW and P can also be observed: AW was typically lower during wetter years with higher P, and vice versa. However, AW in any given year was dependent on the seasonal timing of P relative to crop ET demands, overall crop ET demands, and other factors (e.g., root zone soil moisture carryover from the prior year, surface water availability).

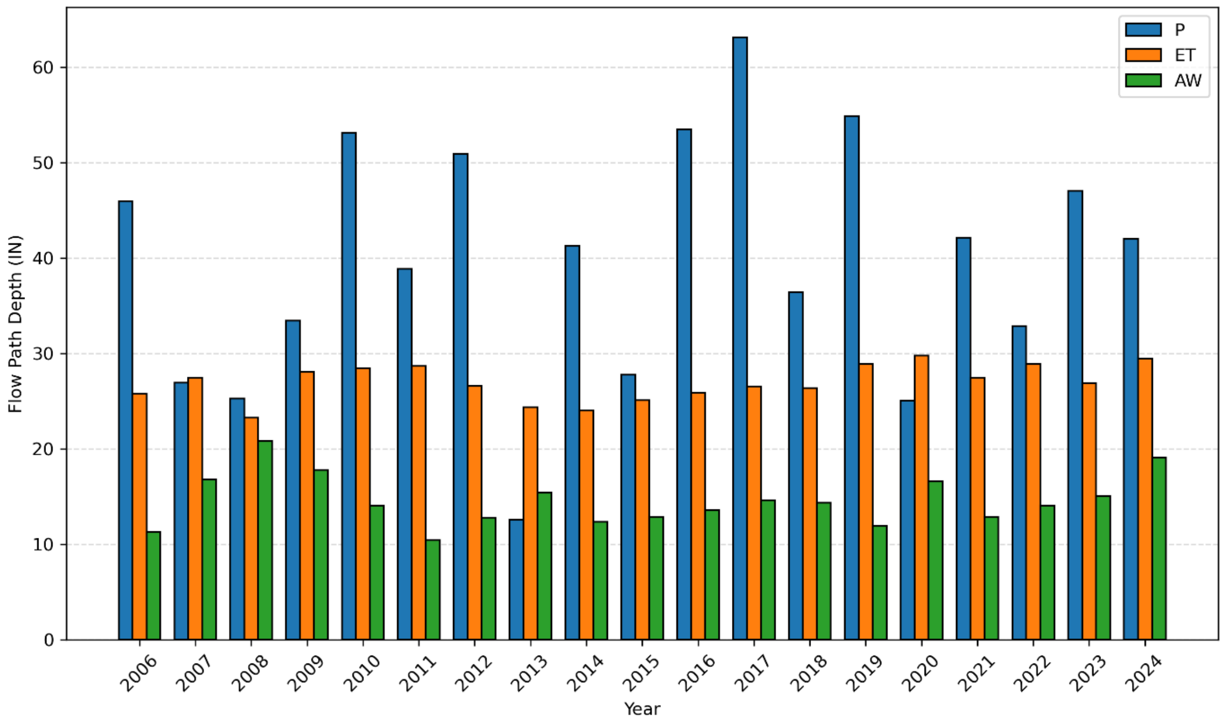

Figure 3-16. A bar chart depicting annual AW, ET, and P for 11 irrigation units with available data during the period from 2006 to 2024. Total volumes for each flow path across the 11 irrigation units were divided by total irrigated area to determine area-weighted average depth in inches (IN).

Finally, the evaporative index (equal to ET divided P) was used to quantitatively evaluate 2024 to long-term average conditions over the period from 2006 to 2024. The evaporative index is a measure of total ET demand (outflows) relative to the P inflows for a specified area over time. Index values less than one signify more precipitation flows into the area than ET out of the area (which is common, because not all P results in ETPR); index values greater than one signify more ET flows out of the area than P flows in. To the extent that ET outflows are greater than the ETPR resulting from P, AW inflows and the resulting ETAW make up this difference. The annual evaporative index values from 2006 to 2024 are shown in **Figure 3-17**. They ranged from less than 0.5 to nearly 2.0 with an overall average value of 0.77. The 2024 value is 0.70 (0.07 lower than the average, or 9% lower relative to the average). This slightly lower value indicates that there was more P relative to ET than on average during the period from 2006 to 2024 for these irrigation units, although the value is relatively close to the long-term average considering the variability in index values observed over time.

Based on this analysis, values for AW, P, and ET in 2024 were higher than long-term averages, but the evaporative index results compared reasonably well to long-term average conditions. As described earlier, these results are based on a limited sample size of 11 irrigation units (sample size was constrained by limited historical AW data availability). Also, there was substantial variability from year to year in values for these flow paths and the evaporative index (with exception of ET, which had less variability relative to other parameters).

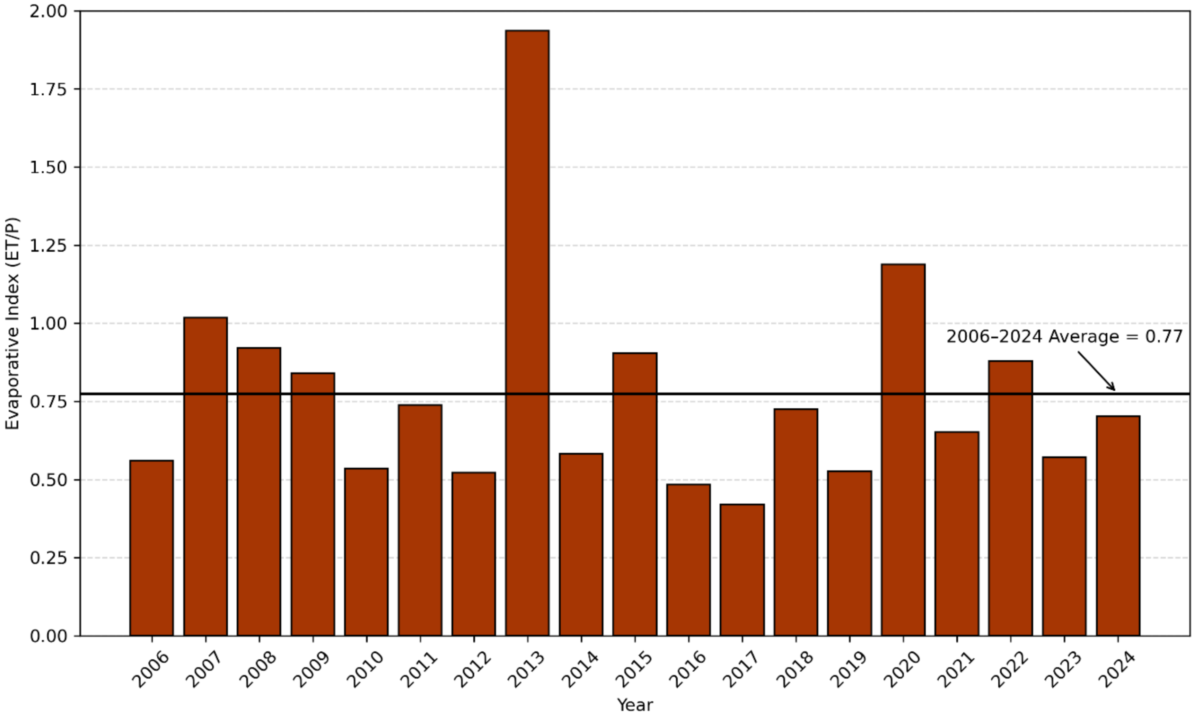

Figure 3-17. A bar chart depicting evaporative index results for 11 irrigation units with available data during the period from 2006 to 2024. The evaporation index was calculated as ET divided P, and the values ranged from less than 0.5 to nearly 2.0 with an average value of 0.77. The 2024 value was 0.70.

3.3.6 In-Field Soils Data Collection

Table 3-3 shows the comparison between the SSURGO estimates and field-verified values of percent sand and clay, and overall soil texture. On average, SSURGO tended to overestimate percent clay and underestimate sand content in the fields, relative to field samples. As a result, clay modifiers were typically added to the overall soil texture from the SSURGO dataset compared to field samples (e.g., Sand Clay Loam vs. Sandy Loam). Soil with higher clay content tends to have a higher water holding capacity compared to lower clay content soil, thus potentially leading to overestimates of available water holding capacity in the IDC model, although more work would be needed to review and test this hypothesis. More details about this analysis can be found in **Appendix D**.

Table 3-3. Comparisons between field soil samples analyzed in the UC Davis Analytical Lab (UC Davis) and data estimated using the Soil Survey Geographic Database (SSURGO). Percent sand, percent clay, and overall soil texture are shown.

Field ID	Percent Sand		Percent Clay		Soil Texture	
	UC Davis	SSURGO	UC Davis	SSURGO	UC Davis	SSURGO
1	72	67	8	15	Sandy Loam	Sandy Loam
2	72	67	8	15	Sandy Loam	Sandy Loam
3	71	67	7	15	Sandy Loam	Sandy Loam
4	53	58	10	21	Sandy Loam	Sandy Clay Loam
5	65	58	8	21	Sandy Loam	Sandy Clay Loam
6	28	39	32	24	Clay Loam	Loam
7	43	53	17	21	Loam	Sandy Clay Loam
8	43	40	25	21	Loam	Loam
9	51	40	13	22	Loam	Loam
10	26	37	33	29	Clay Loam	Clay Loam
11	42	27	16	21	Loam	Silt Loam
12	36	35	25	31	Clay Loam	Clay Loam
13	36	26	23	21	Loam	Silt Loam

This analysis had a few limitations. First, soils are generally heterogeneous, so sampling location can have a significant impact on the soil results obtained from the lab. While samples were pooled and aggregated at all field sites, five samples per field was a limited number of sampling locations compared to the acreage of most fields. Second, estimates from SSURGO were averaged between a depth of 0 to 10 inches within the soil profile while only one sample was taken between 8 to 12 inches in the field. The vertical averaging done for SSURGO data may lead to additional differences compared to the field samples which were only taken in one depth.

Overall, with a few exceptions, the field-tested percentages of sand were within roughly 5-10 percent of the values from SSURGO data while the field percentages of clay were within roughly 20-30 percent. The soil textures generally aligned between the two methods (with the clay modifier noted above in three cases, and a silt modifier in two fields). These results generally indicated that the SSURGO data used in the model aligns reasonably well with conditions observed in the field, although the analysis had the limitations described above and was also limited in scope.

4 Conclusions

The overall objective of this Study was to validate the 2020 Report's agricultural applied water requirements based on modeled estimates. Assembling independent data of actual measurements for review, refinement, or calibration of modeled results is a crucial step to validate modeling results by comparing how model inputs and assumptions align with actual measured values.

This Study was broad in scope and involved a substantial level of effort, including an extensive field data collection program including outreach and coordination with over 20 participating growers during the Study, as well as assembling, processing, and analyzing a wide range of additional data. The data generated through this Study allowed for the comparison of Study results to the modeling results from the 2020 Report. This Study substantially increased the understanding of actual existing conditions for irrigated agriculture in El Dorado County and revealed some important conclusions and differences between the Study dataset and the 2020 Report's modeling results.

The data collected, aggregated, and evaluated to support the Study objective included: precipitation (P), evapotranspiration (ET), evapotranspiration of precipitation (ETPR), evapotranspiration of applied water (ETAW), the consumptive use fraction (CUF), distribution uniformity (DU), and applied water (AW). **Table 2-1** provided in **Section 2** depicts each of these parameters along with a description of the modeling approach based on the 2020 Report and the validation approach and method used in this Study, along with a name for each parameter shown in *italics*. This approach allows for evaluation and validation or potential refinement of each parameter as part of the Study. All these parameters affect the applied water volumes.

A summary of the comparison between the 2020 Report's modeling approach and this Study's validation approach for each of these flow paths and parameters is shown below in **Table 4-1**, along with a validation summary of the results of the comparison. The P comparison showed close agreement with a less than 5% difference observed between P-PRISM and P-NOAA. Total ET and ETAW both showed ET results from IDC model from the 2020 Report were lower than OpenET results. ET estimates modeled in IDC for 2024 (ET-IDC and ETAW-IDC) were 13% and 33% lower, respectively, than OpenET results for participating lands in 2024.

CUF values are anticipated to range from around 0.60 to 0.90 from less efficient applications of AW to more efficient applications; the assumed CUF value from the 2020 Report was 0.80 and was estimated to be a conservative value (i.e., potentially higher than actual CUF values). The CUF calculated based on the 2020 model (ETAW-IDC) and measured applied water through Study (AW-WM) resulted in a lower than expected value of 0.52. However, substituting ETAW-OpenET in the calculation (which was 50% higher relative to ETAW-IDC) increased the CUF to a value of 0.78 (within 3% of 0.80 assumption from the 2020 Report). DU testing was also completed as part of field data collection, and the median value for DU, which represents an upper limit for the CUF, was equal to 0.75 (near the center of the anticipated range of CUF values). These results indicated that the 2020 model underestimated ET and ETAW, and assumed a CUF value that was higher than actual CUF values likely are for existing irrigated agriculture in EDC (as acknowledged in the 2020 Report).

The AW estimated in the 2020 Report (AW-IDC equals ETAW-IDC divided by CUF-0.8) was 35% lower than AW measured through water meters (AW-WM). As described above, this difference is influenced by ET and CUF estimates. If OpenET data (ETAW-OpenET, 50% higher relative to ETAW-IDC) are divided by CUF-0.8, the difference is reduced so that AW-OpenET is only 2% lower than AW-WM. If the CUF is additionally reduced to CUF-DU, the resulting AW (AW-OpenET-CUF-DU) estimated is 4% higher than AW-WM. These changes demonstrate how altering values and assumptions from the 2020 Report impact estimated AW requirements and can more closely align them with measured values.

Table 4-1. Summary of average results from modeling and validation approaches, along with calculation of percent difference of modeling approach relative to validation approach. A validation summary is also included.

Parameter	Modeling Approach[1]	Model Results (IN or unitless for CUF)	Validation Approach[2]	Validation Results (IN or unitless for CUF)	% Difference	Validation Summary
P	P-PRISM	3.77	P-NOAA	3.64	4%	PRISM is approximately 4% greater than NOAA based on monthly comparison of four NOAA station and PRISM grid cells.
ET	ET-IDC	24.3	ET-OpenET	27.9	-13%	ET-IDC was 13% lower than OpenET for participating lands in the Study in 2024 (ET-IDC would need to be increased by 15% to match ET-OpenET).
ETPR	ETPR-IDC	17.1	ETPR-IDC	17.1	-	The same ETPR values for validation comparisons.
ETAW	ETAW-IDC	7.2	ETAW-OpenET	10.8	-33%	ETAW-IDC was 33% lower than OpenET for participating lands in the Study in 2024 (ETAW-IDC would need to be increased by 50% to match ETAW-OpenET).
CUF	CUF-0.8	0.80	CUF-IDC	0.52	53%	The assumed CUF value of 0.8 was 53% higher than CUF calculated from ETAW-IDC and AW-WM.
		0.80	CUF-OpenET	0.78	3%	The assumed CUF value of 0.80 was 3% higher than CUF calculated using ETAW-OpenET and AW-WM.
		0.80	CUF-DU	0.75	7%	The assumed CUF value of 0.80 was 7% higher than the median value from field measurements of DU.
AW	AW-IDC	9.0	AW-WM	13.8	-35%	Modeled AW from IDC (AW-IDC) using the assumed CUF of 0.8 was 35% lower than water meter validation measurements of AW (AW-WM).
	AW-OpenET	13.5		13.8	-2%	Modeled AW from OpenET (AW-OpenET) using the assumed CUF of 0.8 was 2% lower than AW-WM measurements.
	AW-OpenET-CUF-DU	14.4		13.8	4%	Modeled AW from OpenET using the CUF-DU of 0.75 (AW-OpenET-CUF-DU) was 4% greater than AW-WM measurements.

1. The data sources, assumptions, and calculations for the prior modeling approach are described in the 2020 Report, specifically Section 6 and Appendix D. The exception to this is applied water (AW), for which the modeling approach also uses data collected during the Study to calculate estimated AW requirements.
2. The validation approach utilizes data provided by this Study, except for Evapotranspiration of Precipitation (ETPR) which uses the IDC model from the 2020 Report.

The Study results showed measured AW volumes substantially higher than modeled AW volumes from the 2020 Report and indicated that two factors influencing this difference were ET and CUF: the modeled ET estimates using methods from the 2020 Report were lower than results from this Study and the assumed CUF value of 0.80 from the 2020 report was higher than results from this Study. **Table 4-2** is a contingency table (also known as a cross tabulation) that displays the relationship between two variables. In this case, it presents the estimated AW volumes (and percentage increases, relative to the estimated baseline value, in parentheses) resulting from a variety of increased ET and decreased CUF scenarios for F50H (model run 2 from the 2020 Report)[27], rounded to the nearest thousand AF. The increased ET is shown in four increments of a 0, 5, 10, and 15% increase relative to ET-IDC; the 15% increase would match the ET-OpenET results for the Study. The CUF values included are 0.80 (CUF-0.8), 0.78 (CUF-OpenET), and 0.75 (CUF-DU). The values within the table show the AW volumes (and percentage increases in parentheses) associated with each ET and CUF value. All volumes in Table 4-2 below were rounded to the nearest thousand AF.

Table 4-2. Applied Water Requirements (acre-feet, AF): Table summarizing impacts of changes to ET and CUF on overall estimated AW requirements in AF. A variety of increasing ET and decreasing CUF values are depicted, along with the estimated applied water requirement associated with each (and percentage increase relative to the baseline value in parentheses). The initial value of 47,000 AF is equal to the estimated AW requirements for F50H (model run 2). With a 15% increase of ET and CUF equal to 0.75 the estimated AW requirements increase to 75,000 AF (60% increase).

% Increase in ET Relative to 2024 ET-IDC	Consumptive Use Fraction (CUF)		
	0.80	0.78	0.75
0%	47,000 (0%)	48,000 (2%)	50,000 (6%)
5%	55,000 (17%)	56,000 (19%)	59,000 (26%)
10%	63,000 (34%)	64,000 (36%)	67,000 (43%)
15%	71,000 (51%)	72,000 (53%)	75,000 (60%)

The results in the table above depict the sensitivity of estimated AW to changes in ET or CUF values. The decrease in CUF from 0.80 to 0.75 increased the estimated AW by 3,000 or 4,000 AF (roughly 6 to 9%, relative to the 47,000 AF baseline estimate). The increase in ET had a larger impact. Although the increase in ET shown was a maximum of 15%, the majority of ET is ETPR and met by precipitation as a constant, and the minority of ET as ETAW is what increased. Since ETAW was a smaller value than total ET, it was more sensitive to overall changes, and a 15% increase in total ET resulted in an increase in estimated AW of over 50%. As shown above, a 15% increase in total ET while holding CUF value 0.80 aligned the estimated AW requirements within 2% of AW measured through water meters as part of the Study. The total estimated AW increased by 51% relative to the baseline estimate under this scenario.

Table 4-3 shows how increasing the total ET by 15% to match that observed in OpenET data, along with decreasing the CUF to 0.78 (CUF-OpenET, the value calculated using ETAW-OpenET and AW-WM) or to 0.75 (CUF-DU, the median value from DU testing), will influence the estimated applied water

[27] All results in the 2020 Report were in reference to E50H (model run 1), which included existing cropping, existing crop ET, and historical climate. The only difference between E50H and F50H (model run 2) is that existing cropping is substituted for future cropping. F50H is utilized here in order to calculate a total estimated applied water volume for future cropping development but existing crop ET and historical climate conditions; this applied water volume is 47,000 AF (rounded to nearest 1,000 AF) as shown in **Table 4-2** for 0% ET increase and CUF equal to 0.80 (EDWA, 2020).

requirements under future cropping and climate scenarios for all nine model runs completed during prior work (EDWA, 2020). These calculations assume that conditions during the 2024 Study were representative of long-term average conditions used to estimate applied water requirements in the 2020 Study (i.e., that conditions in 2024 for P, ET, and AW were representative of long-term average conditions between 1998 and 2017 and into the future). Based on historical data provided in this Study, the precipitation in 2024 was near average for the period from 2006 to 2024. All volumes in Table 4-3 below were rounded to the nearest thousand AF.

Table 4-3 Summary of changes to estimated applied water requirements (rounded to the nearest thousand AF) due to adjustments to total ET and CUF based on Study results. ET-1.15 represents a 15% increase in total ET, and CUF-0.XX represents various CUF values used to calculate AW requirements based on ETAW results. To the extent the 2024 Study period is representative of long-term average conditions (see Section 3.3.5 for details on how 2024 compares to prior years), these values show how estimated applied water requirements would be impacted based on Study results. It also depicts which three of the nine model runs were included in the Executive Summary of this Study.

Model Run	Cropping Scenario	Climate Scenario	Applied Water Requirements by Scenario (Volume in acre-feet, AF)				Included in Executive Summary
			2020 Report Results	ET-1.15-CUF-0.80	ET-1.15-CUF-0.78	ET-1.15-CUF-0.75	
1	Existing	Historical	6,000	9,000	9,000	10,000	
2	Future	Historical	47,000	71,000	72,000	75,000	
3	Future	Historical	60,000	90,000	92,000	96,000	
4	Future	CT2040	68,000	102,000	105,000	109,000	X
5	Future	CT2055	73,000	110,000	112,000	117,000	
6	Future	HD2040	73,000	110,000	112,000	117,000	
7	Future	HD2055	78,000	117,000	120,000	125,000	X
8	Future	WW2040	64,000	96,000	98,000	102,000	X
9	Future	WW2055	65,000	98,000	100,000	104,000	

The impacts of increasing ET and decreasing CUF values on estimated AW can be observed for the various model runs. Model runs 8, 4, and 7 represent the low, middle, and high estimates of projected AW requirements, respectively, and were included in the executive summary. Under model run 4 (the middle estimate), the 2020 Report showed estimated AW requirements of 68,000 AF (EDWA, 2020). Increasing ET and/or decreasing the CUF resulted in increases to AW requirements to between 102,000 AF and 109,000 AF (increases of 50% to 60% relative to the estimates from the 2020 Report). Although adjustments to total ET (increase of 15%) and CUF (decreases of 0.02 and 0.05) are much smaller, since the majority of total ET is met by ETPR and ETAW only represents a minority of total ET, any adjustments to ETAW can have a relatively large impact on total estimated AW requirements. As described above, the 15% increase in total ET represents a 50% increase in ETAW, relative to the estimates from the 2020 Report.

The Study results show that the 2020 Report's modeling work used conservative inputs and assumptions that led to conservatively low estimates of applied water demands. Actual measurements of applied water in 2024 as part of this Study were substantially higher than the estimates from the 2020 Report. The Study results provide increased understanding of existing conditions and a basis for potential refinement of the 2020 estimates of applied water requirements to inform future planning efforts.

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6 Appendices

Appendix A – Summary of Collaborator Coordination and Associated Factsheets

Appendix B – Review and Validation of PRISM Precipitation Data with Ground-based Weather Station Data

Appendix C – Estimation of Water Volumes for Various Purposes on Water Meters Measuring Water for Multiple Purposes

Appendix D – Summary of SSURGO Estimated and Field Verified Soil Data

TECHNICAL MEMORANDUM

To: El Dorado Water Agency (EDWA)

From: Davids Engineering (DE)

Date: June 28, 2024

Subject: **Summary of Collaborator Coordination and Roles (as part of Applied Water Validation Study)**

1 Introduction

This technical memorandum (TM) summarizes the potential study collaborators, coordination with collaborators, and the potential activities for study collaborators in support of EDWA's Applied Water Validation Study (Study), which is being led by DE.

The potential collaborators identified through coordination between EDWA and DE were:

1. El Dorado County Agriculture Department (EDC Ag. Dept.)
2. El Dorado Farm Bureau (EDFB)
3. University of California Cooperative Extension (UCCE)
4. Irrigation Management Services (IMS) Contractors
5. El Dorado Wine Grape Growers Association (EDWGGA)
6. Apple Hill Growers Association (AHGA)

Coordination with potential collaborators, collaborator interest, and anticipated collaborator roles are described subsequently.

2 Summary of Collaborator Coordination and Potential Activities

Coordination with potential study collaborators was conducted between October 2023 and April 2024. A factsheet for collaborators was developed that summarized the Study, its background and purpose, and the need for support from local agencies as collaborators (Appendix A). It also listed potential activities that collaborators could participate in to support the Study (Table 4), along with a description of the activity (including level of effort), and anticipated schedule. After finalization, the factsheet was distributed via email to the potential study collaborators listed above. A factsheet for potential growers was also developed and distributed to potential study collaborators to distribute to potential "cooperating growers" (Appendix A).

Between October 2023 and April 2024, communication and coordination with potential collaborators was conducted via email, phone calls, and in-person and virtual meetings to discuss the Study and potential roles for each collaborator. The meetings also focused on the need for grower outreach in the near-term to identify potential "cooperating growers" and complete field inspections in preparation for data collection during the 2024 irrigation season. Collaborators distributed study information to their members or stakeholders, and DE and EDWA had the opportunity to publicly present the Study to the EDWGGA in February 2024 and to the EDC Ag. Dept. in March 2024.

Appendix A – Summary of Collaborator Coordination and Associated Factsheets

Table 4. Potential Collaborator Activities, Level of Effort, and Schedule.

Activity	Description and Level of Effort	Schedule
"Cooperating Growers" Recruitment	• Develop and provide list of potential Cooperating Growers • Make initial contact with potential Cooperating Growers	Through January 2024
Coordinate with other past or ongoing irrigation research projects	• If aware of other related projects that may complement this study, or vice versa, share project details with EDWA and technical team	At any time, as applicable
Plan Reviewer	• Provide review and feedback on preliminary study results and findings	As needed (depending on timing and availability) between now and Early 2025
Outreach	• Help disseminate study information and findings to interested groups and the public via email, social media, meetings, etc.	As needed (depending on timing and availability) between Spring 2024 and Early 2025
Intern Identification	• Assist in identifying one or two technically qualified, ideally local, student interns for Summer 2024 who can conduct field data collection under the supervision of professional staff and technical consultants.	Through Spring 2024
Field Support	• Donate staff time to support field data collection. The level of effort is dependent on staff availability, but could range from a single field visit to better understand the data collection to participation in data collection on a regular basis (e.g. weekly, monthly).	During the 2024 Irrigation Season

3 Collaborator Interest and Potential Collaborator Roles

Although participation in activities may change over time as collaborator interest and capacity change, the anticipated activities that each collaborator plans to participate in to support the Study are shown below in Table 5.

Appendix A – Summary of Collaborator Coordination and Associated Factsheets

Table 5. Summary of Collaborators and Their Potential Roles.

Activity	Potential Collaborators[1]					
	EDC Ag. Dept.	**EDFB**	**UCCE**	**IMS Contractors**	**EDWGGA**	**AHGA**
"Cooperating Growers" Recruitment	✓	✓	✓	✓	✓	✓
Coordinate with other past or ongoing irrigation research projects			✓	✓		
Plan Reviewer						
Outreach	✓	✓	✓		✓	
Intern Identification						
Field Support		✓				

The primary role thus far that collaborators have supported the Study is through outreach and recruiting "cooperating growers" as every collaborator shared the opportunity to participate with their Boards, members, and/or stakeholders. Some recruitment led to direct grower engagement for study participation. However, additional individual outreach by DE staff was required to solicit enough participation to achieve the desired number of "cooperating growers" for the Study. This outreach by DE staff was likely more successful since growers were already aware of the Study and its objectives through collaborator outreach.

A few collaborators have expressed interest in coordination related to other irrigation research projects in El Dorado County, and one collaborator expressed interest in providing field support during the 2024 irrigation season. There was no interest in identifying student intern candidates, and no interest thus far in reviewing preliminary Study results and findings, although those are not yet available.

Overall, the collaborator coordination effort was successful in outreach and recruitment of "cooperating growers" (although additional direct outreach by DE staff was still required for full recruitment). Efforts such as this require additional time and effort to complete, but can be helpful in building relationships with the potential collaborators and "cooperating growers" in El Dorado County.

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[1] The potential collaborators shown in Table 2 are the El Dorado County Agriculture Department (EDC Ag. Dept.), El Dorado Farm Bureau (EDFB), University of California Cooperative Extension (UCCE), Irrigation Management Services (IMS) Contractors, El Dorado Wine Grape Growers Association (EDWGGA), and the Apple Hill Growers Association (AHGA).

October 2023

El Dorado County West Slope Agricultural Development Feasibility Assessment Applied Water Validation Study for Irrigated Agriculture

Project Information for Potential Collaborators

Background and Purpose

In El Dorado County, agriculture is a way of life. Farms, orchards, vineyards, and pastures not only embody the geography, they represent the county's character and support a rural-agricultural lifestyle that both residents and tourists value. Recognizing the importance of the rural-agricultural economy, El Dorado Water Agency (EDWA) recently worked with the County Agricultural Commissioner and local growers to prepare estimates of applied water demands associated with potential future expansion of irrigated agriculture in the West Slope. Acquiring water rights sufficient to meet these future demands, along with future municipal and industrial demands, will allow the County to continue to support both the economic growth and rural-agricultural lifestyle envisioned in its adopted General Plan.

The applied water demands were estimated using locally calibrated crop coefficients based on remotely sensed actual crop ET data and root zone water budget modeling using DWR's IDC model1, but were not validated through comparison to actual on-the-ground water demands and use. A new phase of work is underway to partner with collaborating agencies and growers to collect in-field applied water data to characterize existing irrigation water use that will then be used to validate and potentially refine the applied water estimates from prior work.

We Need Your Help as a Collaborator!

EDWA hopes to tap into the vast, local agricultural knowledge through collaboration with the County Agricultural Commissioner, County Farm Bureau, University of California Cooperative Extension, Irrigation Management Services, and other organizations that express interest.

We would appreciate your assistance as a Collaborator. As a Collaborator, your agency could help support one or more of the following activities:

ACTIVITY	DESCRIPTION & LEVEL OF EFFORT	SCHEDULE
"Cooperating Growers" Recruitment	• Develop and provide list of potential Cooperating • Growers Make initial contact with potential Cooperating Growers	Now through January 2024
Coordinate with other past or ongoing irrigation research projects	• If aware of other related projects that may influence or improve this study, or vice versa, share project details with EDWA and technical team	At any time, as applicable
Plan Reviewer	• Provide review and feedback on preliminary project results and findings	As needed (depending on timing and availability) between now and Early 2025
Outreach	• Help disseminate project information and findings to interested groups and the public via email, social media, meetings, etc.	As needed (depending on timing and availability) between Spring 2024 and Early 2025
Intern Identification	• Assist in identifying one or two technically qualified, ideally local, student interns for Summer 2024 who can conduct field data collection under the supervision of professional staff and technical consultants.	Now through Spring 2024
Field Support	• Donate staff time to support field data collection. The level of effort is dependent on staff availability, but could range from a single field visit to better understand the data collection to participation in data collection on a regular basis (e.g. weekly, monthly).	During the 2024 Irrigation Season

For more information, or to discuss your agency's potential collaboration, please contact Rebecca Guo, EDWA General Manager, at (530) 718-8772 or rebecca.guo@edcgov.us.

Thank you for your interest.

October 2023

El Dorado Water Agency

El Dorado County West Slope Agricultural Development Feasibility Assessment Applied Water Validation Study for Irrigated Agriculture

Project Information for Potential Cooperating Growers

Background and Purpose

In El Dorado County, agriculture is a way of life. Farms, orchards, vineyards, and pastures not only embody the geography, they represent the county's character and support a rural-agricultural lifestyle that both residents and tourists value. Recognizing the importance of the rural-agricultural economy, El Dorado Water Agency (EDWA) recently worked with the County Agricultural Commissioner and local growers to prepare estimates of applied water demands associated with potential future expansion of irrigated agriculture in the West Slope. Acquiring water rights sufficient to meet these future demands, along with future municipal and industrial demands, will allow the County to continue to support both the economic growth and rural-agricultural lifestyle envisioned in its adopted General Plan.

The applied water demands were estimated using locally calibrated crop coefficients based on remotely sensed actual crop evapotranspiration data and root zone water budget modeling using DWR's IDC model, but were not validated through comparison to actual on-the-ground water demands and use. A new phase of work is underway to partner with collaborating agencies and growers to collect in-field applied water data to characterize existing irrigation water use that will then be used to validate and potentially refine the applied water estimates from prior work.

We Need Your Help as a Cooperating Grower!

In order to collect in-field applied water data and complete this work, we need to identify and partner with active growers in El Dorado County. Growers who voluntarily participate will help support the potential future expansion of irrigated agriculture in El Dorado County, and along with it, continued economic growth and promotion of its unique rural-agricultural lifestyle. Additionally, all data collected will be shared with participating growers for their own knowledge and use in management of their agricultural lands.

Our goal is to identify about thirty (30) "Cooperating Growers" and document their existing irrigation systems and practices during the upcoming (2024) irrigation season through field data collection. Cooperating Growers are established growers in the West Slope and will be selected to represent the following range of crops, locations, and conditions:

Crop Types

- Vineyards
- Apple Orchards
- Miscellaneous Deciduous (e.g. walnuts, pears, peaches, plums, cherries, etc.)
- Irrigated Pasture
- Christmas Trees

Locations and Conditions

All locations on the West Slope will be considered, but the study goal is to include growers across the variety of West Slope locations and conditions where there is currently irrigated agriculture. The parameters that will be evaluated for inclusion include geographic location and information on farm and field size, elevation, land slope, and soils.

Cooperating Growers and their associated lands must meet the following criteria to be eligible for participation in the study:

- Willingness to **provide access to lands** for data collection.
    - Access is anticipated to include a single site visit during the 2023/2024 winter to establish current conditions and plan for monitoring, and periodic, regular site visits during the 2024 irrigation season for data collection. The site visits will primarily be conducted by technical consultants working on behalf of EDWA, as coordinated and agreed upon prior to the site visits.

- Willingness to **share data collected** for purposes of the study and inclusion in a final report.
    - Note: Individual data will be protected (meaning the identity of growers belonging to a particular data set will be masked), and all data published or released to the public will be in aggregate, averaged, or summarized form. We will make individual results available with the respective Cooperating Grower for their own knowledge and use in management of their agricultural lands.

- Ability to **continuously measure irrigation water deliveries** (either surface water deliveries or pumped groundwater) to quantify applied water volumes over time.
    - It is anticipated that some potential growers (potentially within El Dorado Irrigation District) may have a single flowmeter that measures both irrigation and domestic water deliveries. If this arises, these cases will have to be evaluated as to whether measurement records can be adjusted to account for the municipal use component.

- Ability to **associate applied water deliveries with the final place of use** (i.e., a defined field or set of fields).
    - Preference will be given to growers who have a single crop and irrigation method (e.g., drip irrigation) associated with a delivery point(s). Having multiple crops or irrigation methods does not automatically result in exclusion from the study.
    - Growers who may have multiple delivery points and fields may have multiple areas considered for potential inclusion in the study.
    - Resources are being explored to assist cooperating growers in installing water delivery measurement devices if such devices currently do not exist or are not sufficiently reliable.

For more information, or to discuss your agency's potential collaboration, please contact Rebecca Guo, EDWA General Manager, at (530) 718-8772 or rebecca.guo@edcgov.us.

Thank you for your interest.

TECHNICAL MEMORANDUM

To: El Dorado Water Agency

From: Davids Engineering, Inc.

Date: March 31, 2025

Subject: **Review and Validation of PRISM Precipitation Data with Ground-based Weather Station Data**

Summary

Due to the limited spatial and temporal coverage of weather stations (e.g., National Oceanic and Atmospheric Administration, NOAA) on the West Slope in El Dorado County, monthly precipitation values were obtained from PRISM[1] for the 1998-2024 period. PRISM uses local weather stations, a digital elevation model (DEM), and other spatial datasets to generate gridded precipitation estimates. PRISM was used as precipitation data input for the Integrated Water Flow Model Demand Calculator (IDC) model developed as part of the *El Dorado County Agricultural Development Feasibility Assessment* (2020 Report). To evaluate accuracy and variability of the PRISM precipitation results, we compared these modeled precipitation data with NOAA quality-controlled measured precipitation data at a monthly and annual timescale. This TM describes the methodologies and results for reviewing and validating the PRISM precipitation data. The findings from this ground-truthing comparison are used to support the precipitation analysis in the Applied Water Validation Study (Study – DE, 2025).

1 Introduction

In El Dorado County (EDC), precipitation is the primary source of water inflow to support agricultural production (e.g., it is a larger inflow to agricultural areas than applied water for irrigation). Therefore, understanding the temporal and spatial variability of precipitation on the West Slope is crucial, particularly in the western region where irrigated agriculture is located. While precipitation generally meets the majority of crop water demand, the remaining demand must be satisfied through irrigation (i.e., applied water). Given that the overarching goal of the Study is to estimate current and future applied crop water demand, accurately quantifying precipitation is critical for estimating the irrigation needs of agriculture in EDC.

Ground-based weather station data (e.g., from NOAA) are typically considered reliable due to their rigorous quality-control processes. However, these stations are usually located in more populated areas, resulting in limited spatial coverage in remote regions where much of the existing agricultural land in El Dorado County is located. To meet the requirement of data covering the entirety of a model area and the limited availability of point-based precipitation measurements from weather stations or rain gauges, data from the Parameter-elevation Regressions on Independent Slopes Model (PRISM), developed by the PRISM Climate Group at Oregon State University, were used in the development of the 2020 Report and reviewed and evaluated in the Study.

[1] More information available at: http://www.prism.oregonstate.edu/explorer/

PRISM is a gridded dataset that estimates precipitation and other climate parameters across both space and time. It integrates available weather station data with modeled relationships involving topography and other factors influencing weather and climate. PRISM data are available in raster coverages for the entirety of El Dorado County on both daily and monthly timesteps from 1895 through the present, with a spatial resolution of either 4 kilometers (km) x 4 km or 800 meters (m) x 800 m. To evaluate the suitability of PRISM data for this Study, daily observed precipitation data from ground-based NOAA weather stations were collected, aggregated to a monthly and annual timescale, and compared with PRISM estimates.

This technical memorandum (TM) describes the methods used to acquire and process both PRISM and NOAA datasets (Section 2), presents and discusses the results of the comparison analysis (Section 3), and concludes with a summary of findings (Section 4).

2 Methods

To evaluate the PRISM data used in the 2020 Report, daily measured precipitation data were collected from stations maintained by NOAA and available through their California-Nevada River Forecast Center (CNRFC)[2]. Stations located on the western slope of El Dorado County, particularly in areas with irrigated agriculture, were identified. The data were reviewed, and only complete monthly records (i.e., months without missing or questionable data) were used for comparison with PRISM data.

Monthly precipitation values from each NOAA CNRFC station were directly compared to the corresponding monthly PRISM values from the gridded cell in which the station is located. Observed monthly data were also aggregated to an annual scale. As with the monthly analysis, only complete annual records were included in the comparison with PRISM data.

For both monthly and annual comparisons, linear regression was used to assess the relationship between PRISM and observed weather station data. The slope coefficient and coefficient of determination (R^2) were calculated, where values of one would indicate a perfect match between the datasets. Additionally, a histogram was created to examine the frequency distribution of percentage differences between the two datasets.

3 Results

3.1 Linear regression

A total of four NOAA weather stations with at least one complete monthly dataset were identified (Figure 8). These station names are Placerville 3.7 SW, Placerville 6.6 ESE, Placerville IFG, and Cool 2.0 ENE. When comparing PRISM-modeled and NOAA-measured monthly data at respective stations, the strong coefficients of determination (R^2 values > 0.972) and correlation coefficients close to 1 (0.897 < slopes < 1.093) indicated that the PRISM monthly precipitation estimates closely reflected the observed precipitation values.

[2] More information about NOAA CNRFC (including data access) is available at: https://www.cnrfc.noaa.gov/rainfall_data.php

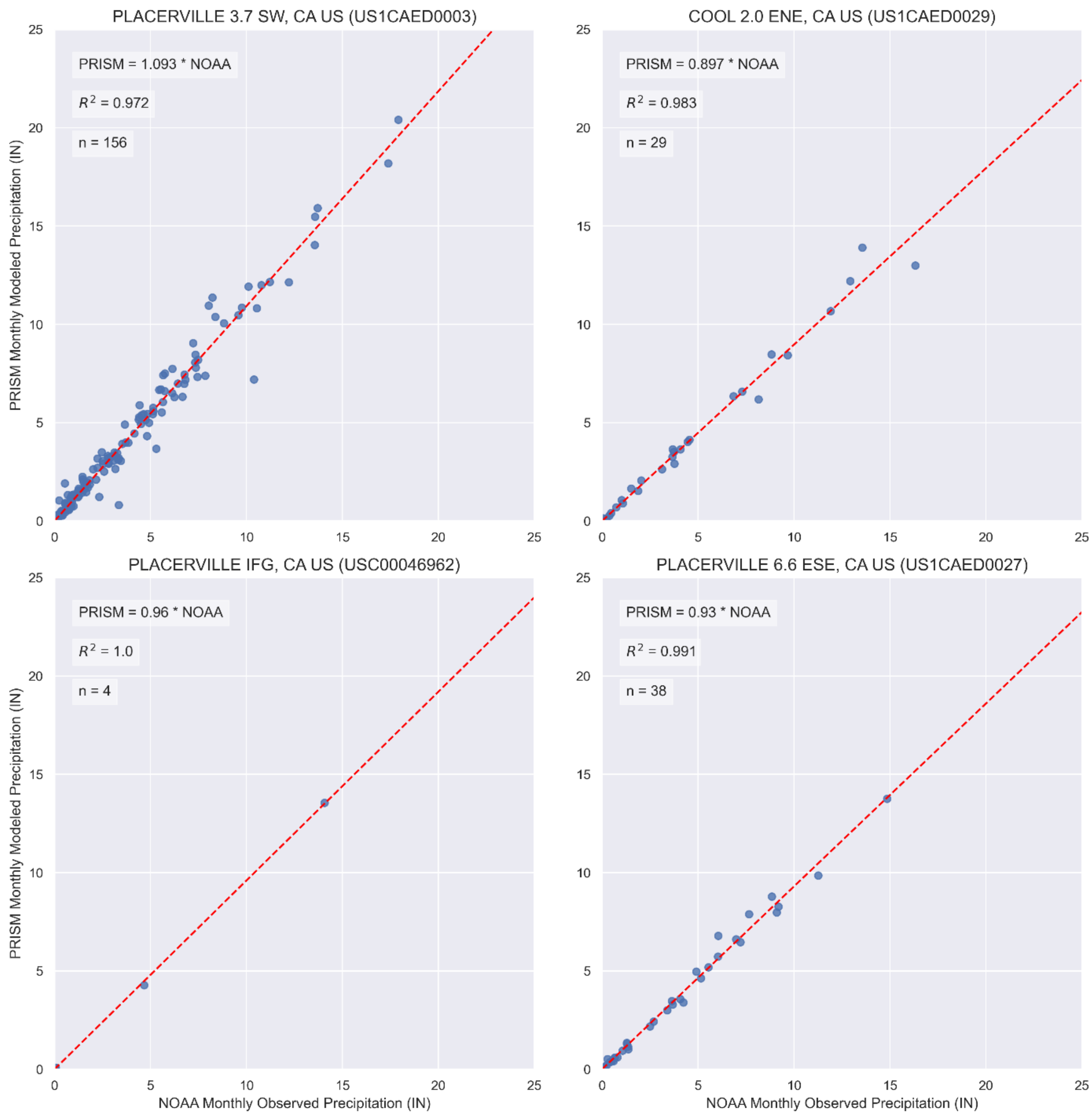

Figure 8. The correlations between PRISM modeled and NOAA observed monthly precipitation at various NOAA weather stations located in Placerville and Cool, CA.

Similarly, the strong coefficient of determination (R^2 = 0.923) and a correlation slope close to 1 (slope = 1.074) indicate that the PRISM annual precipitation estimates also reasonably represented the measured precipitation values from NOAA (Figure 9). Note that not all monthly data shown in Figure 8 were included in the annual analysis presented in Figure 9, as some weather stations did not have complete annual datasets.

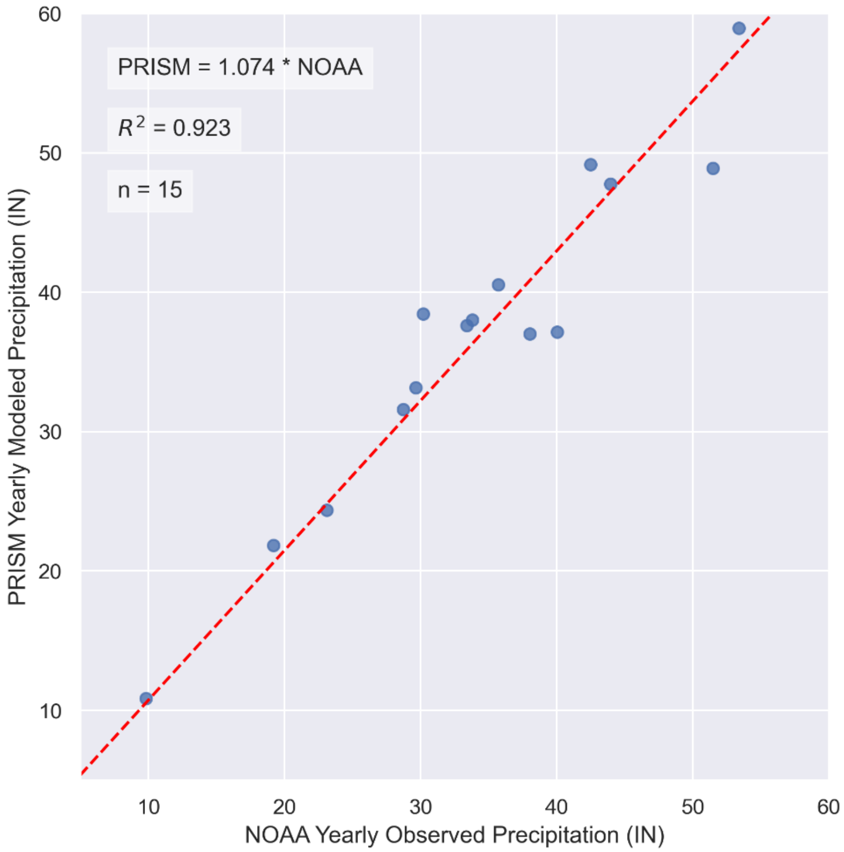

Figure 9. The correlations between PRISM modeled and NOAA observed annual precipitation at various NOAA weather stations located in Placerville and Cool, CA.

3.2 Histogram

As presented in Figure 10 (and Figure 8), some differences were observed between NOAA observed and PRISM modeled monthly precipitation data. However, the majority of differences (65% of all monthly data points) were within 20%. The relatively normal distribution of these differences suggested minimal bias in either underestimation or overestimation. Notably, the larger percentage differences were primarily associated with small precipitation values (Figure 11) and are expected to have relatively small impacts from a volumetric perspective when including precipitation data in the main Study report.

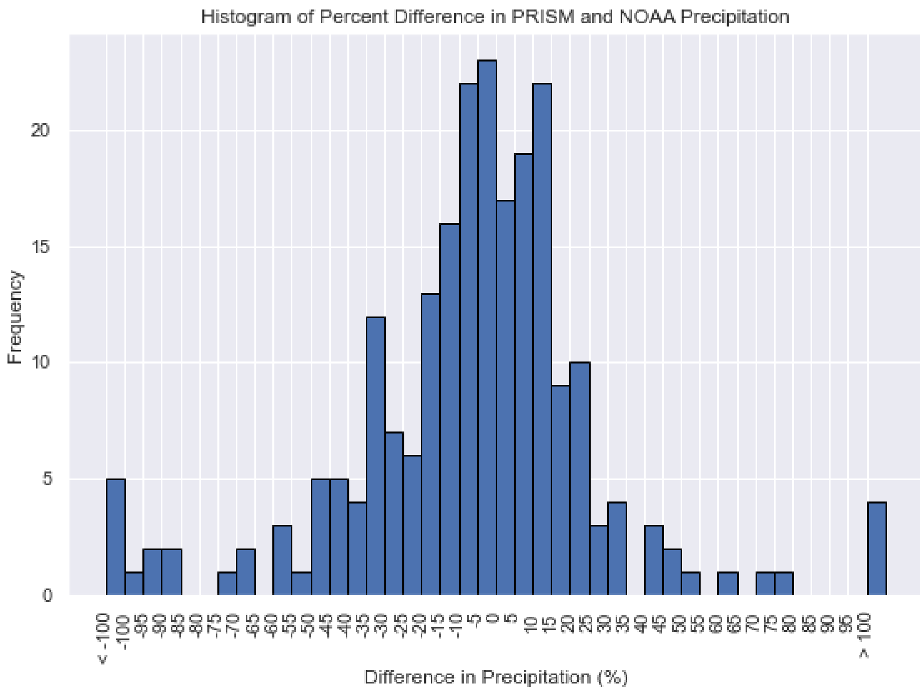

Figure 10. A histogram showing the frequency of occurrence for each bin of percentage difference in NOAA observed and PRISM modeled monthly precipitation data.

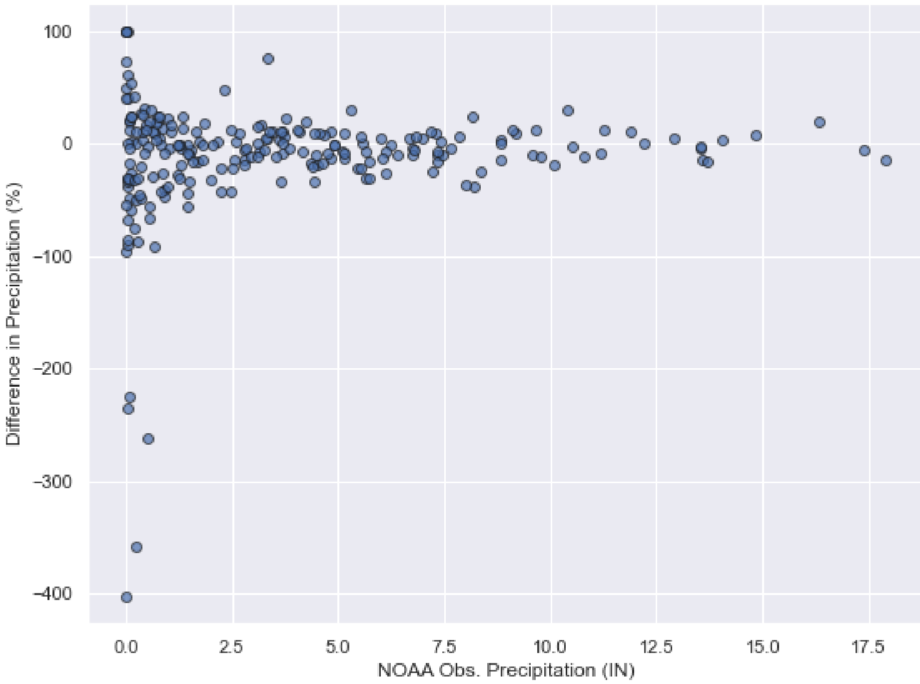

Figure 11. A histogram showing the frequency of occurrence for each bin of percentage difference in NOAA observed and PRISM modeled monthly precipitation data.

4 Discussion and Conclusions

As discussed in the Section 3, PRISM modeled precipitation data were found to be comparable to NOAA observed data at both monthly and annual scales. Therefore, it is reasonable to use PRISM data to provide comprehensive coverage across the entire Study Area, enabling precipitation analysis in regions where ground-based weather stations are absent.

5 References

Davids Engineering (DE). 2025. Applied Water Validation Study for the El Dorado County Agricultural Development Feasibility Assessment. Report prepared for the El Dorado Water Agency.

El Dorado Water Agency (EDWA). 2020. El Dorado County Agricultural Development Feasibility Assessment. Report prepared by Davids Engineering and ERA Economics.

TECHNICAL MEMORANDUM

To: El Dorado Water Agency

From: Davids Engineering, Inc.

Date: 4/28/2025

Subject: **Estimation of Water Volumes for Various Purposes on Water Meters Measuring Water for Multiple Purposes**

Summary

While many participating properties have applied water data from 2024 that can be directly used in the analysis (as described in the Applied Water Validation Study – DE, 2025), not all do. For properties that do not, this was caused by El Dorado Irrigation District (EID) water meters measuring volumes that do not solely represent volumes being applied for irrigation of agriculture. In these cases, the total volume measured by water meters included both water volumes for irrigation of agriculture and one or more other purposes (e.g., domestic). This TM outlines the process developed and implemented to estimate these other water use purposes and summarizes the results. This issue means that the raw water meter data from EID would overestimate applied water for agriculture by not accounting for the volumes for these other purposes.

The estimates of volumes for other purposes on these water meters were then used to adjust (i.e., reduce) total water volumes observed on each meter and for each irrigation unit to the estimated volumes used for irrigation of agriculture prior to the inclusion of these data in the applied water data analysis presented in the Applied Water Validation Study report. As described below, if there was too high of a level of uncertainty in these estimated volumes, the data were excluded in the applied water data analysis and other Study results presented in the Applied Water Validation Study report.

1 Introduction

The overall objective of the Study is to increase confidence in the Integrated Water Flow Model Demand Calculator (IDC) model previously developed through the *El Dorado County Agricultural Development Feasibility Assessment* (2020 Report) for the West Slope of El Dorado County. This was achieved through local in-field and water utility data collection in cooperation and collaboration with participating West Slope growers during the 2024 irrigation season and assembly of publicly available datasets for analysis and comparison to IDC model results from the 2020 Report for either model validation or potential refinement.

Ultimately, the Study aimed to determine independent measurements or calculations of applied water requirements and of a representative Consumptive Use Fraction (CUF) for comparison to modeled and assumed values from the 2020 Report. The increased understanding of existing irrigated agriculture in El Dorado County from these values can be used to validate or refine estimates of future applied water requirements for planning purposes (as done in the 2020 Report). As part of the Study, applied water was measured through observations of totalizing water meters. Some of these meters measure water delivered for multiple purposes including consumptive uses in domestic residences or commercial shops, application for irrigation of agriculture, application for the irrigation of landscaping, and the maintenance of surface water bodies (i.e., ponds or swimming pools). In order to accurately quantify for the volume of water used for irrigation of agriculture (in pursuit of the Study objective), isolating the volume of applied water for the irrigated agriculture by estimating the volume of water used for other purposes and subtracting it from the total volume was necessary for these water meters measuring water for multiple purposes.

This TM will discuss the methods (Section 2) used to quantify volume of water used for domestic residences, commercial shops, irrigated landscaping, and maintenance of surface water bodies, followed by a presentation of the Results (Section 3), Discussion and Conclusions associated with the results (Section 4), and a list of References (Section 5).

2 Methods

2.1 Estimating Mixed Purpose Water Volumes

Consumptive water used for purposes other than the irrigation of agriculture were classified under the following three categories:

1. Indoor uses (i.e., domestic residences and commercial shops),
2. Irrigated landscapes, and
3. Open water bodies.

The procedures used to estimate water volumes associated with use under each of these categories are described below. Irrigation units with commercial processing facilities (such as a winery, bakery, or other food or beverage preparation facility) were not included in this analysis due to the lack of additional information and data (e.g., specific water-using activities and associated volumes, capacity of facilities, timing of activities) to provide reasonable estimates; these irrigation units were also excluded from Study results presented in Applied Water Validation Study report.

All estimated water volumes produced through this analysis were evaluated on a case-by-case basis to assess if the estimated values were reasonable, along with the percentages of total water associated with each purpose type (including agricultural) for the water meter. For irrigation units with questionable water meter data or unreasonable estimates for a given purpose, they were excluded from the data analysis and final results described in the main Applied Water Validation Study report.

a. Indoor Uses

The indoor water usage in this TM refers to water usage in residences and commercial shops. The residential water usage included drinking, washing, and other indoor activities. Commercial shops in this context refer to workshops such as barns, workshops, storefronts, and agricultural service buildings that have similar water usage as the residences but have low occupancies and more limited estimated volumes. These shops do not include commercial processing facilities such as wine processing or food preparation facilities. The indoors water usage values were estimated using the average of up to three different methods (depending on data availability, as described below):

1. Calculating volumes by subtraction

2. Estimating winter water volumes
3. Household per capita consumption and average number of people per household

To calculate volumes by subtraction, the total volume of a downstream water meter measuring only deliveries to irrigated agriculture water consumption was deducted from the total volume of an upstream water meter measuring both irrigated agriculture and indoor deliveries. This approach was only possible for certain properties and irrigation units where there were one or more water meters measuring the total water volumes to the entire property and one or more water meters measuring only the total water volume for irrigation of agriculture in the irrigation unit. For properties without upstream and downstream water meters and a clear delineation between total and irrigated agriculture volumes, this method was not used, and thus, not included in the calculation of the average between the three methods mentioned above.

To estimate winter water volumes, it was assumed that there were no water volumes delivered and used for irrigation of agriculture or other outdoor purposes (irrigation of landscaping or maintenance of surface water bodies) near the end of the calendar year when precipitation may be present and evaporative demands are minimal. Therefore, winter water volumes are an estimation of volumes associated with indoor consumption. The winter water was estimated by calculating the change in water meter volume readings between December and February of historical data (EID collects meter readings every other month and has historical records dating back to as early as 2006, although the number of years of available data vary for each water meter and associated irrigation unit and property). Subsequently, the resulting water meter volumes were divided by the average number of people per household and the number of days between flowmeter data observations to estimate a per capita water consumption (gal/capita/day). The average number of people per residential household in El Dorado County was 2.52 (UCSB, 2024), and the commercial shops were assumed to have half that occupancy (i.e., 1.26). Finally, per capita water consumption was multiplied by the average number of people per household or shop, the number of residences and shops on the property, and 365 days per year to estimate annual indoor water volumes (gal/year) for each applicable property (maintaining the link between water meters and irrigated fields to form irrigation units). The number of residences and shops were determined in coordination with participating growers. For properties without historical data for winter months, this method was not used, and thus, not included in the calculation of average between the three methods mentioned above.

Similar to the winter water usage estimation method, the last method also calculated annual indoor water consumption based on the per capita water consumption, average number of people per household, number of households in the properties, and number of days in a year. The primary difference was the assumption used for the per capita water consumption. In this method, a per capita water consumption of 126 gal/capita/day was assumed, based on the average residential consumption of El Dorado Irrigation District users between 2017 and 2021 (California State Water Resources Control Board, 2024). This method was applied to nearly every property with a water meter associated residences and commercial shops. The exception to this were instances where the first two estimation methods (i.e., calculating volumes by subtraction and estimating winter water volumes) were closely aligned with each other but were notably different from this method. This method was excluded in those instances because the first two methods were more representative of actual conditions with data available specific to that property. Similar to the winter water volumes estimation method, a final number for annual indoor water volumes (in gal/year) was estimated for each property and was included in the average calculation.

b. Irrigated landscaping

The water consumption for irrigated landscaping was estimated using water demands and an assumed consumptive use fraction. The Simplified Landscape Irrigation Demand (SLIDE) Equation (Kjelgren et al. 2016) was used to estimate water demands (ET) for irrigated landscaping. This method multiplied reference ET (ET_o) by the landscape correction factor (K_L) and landscaped area (LA), as described in the equation below:

$$ET_{annual} = \sum (ET_O \times K_L \times LA)_{daily}$$

Where:

ET_O = reference evapotranspiration (IN or FT)
K_L = overall landscape coefficient
LA = landscape area of all plants (FT^2)

Daily ET_o values were obtained from Fair Oaks California Irrigation Management Information Systems (CIMIS)[1] station; the same source used for the IDC model (EDWA, 2020). Because of the differences in ET_o across the elevations present in El Dorado County (i.e., ET_o decreases as elevation increases), the ET_o was multiplied by a zone adjustment factor (**Table 6**). The properties with irrigated landscaping in the Study are only located in Zones 51 and 53.

Table 6. ET_o Zone Adjustment Factors (EDWA, 2020).

ET_o Zone	Zone Adjustment Factor
45	0.809
47	0.854
49	0.879
51	0.921
53	0.956
55	0.987

The K_L was calculated using an area-weighted approach by multiplying a plant species factor (**Table 7**, UCANR, 2024) with landscaped area (LA), as described in the equation below. The total landscaped area (FT_2) of each property was delineated based on the satellite images, field visits, and coordination with growers. We assumed 70%, 15%, and 15% of the landscaped area were occupied by general turfgrass lawn (cool-season), herbaceous perennials, and desert adapted plants, which yielded a K_L of 0.68.

$$K_L = \sum (k_{s,1} \times LA_1)_N$$

where

K_L = overall landscape coefficient
Ks = plant species coefficient
LA = landscape area occupied by a certain plant species (%)

[1] More information about CIMIS is available at: https://cimis.water.ca.gov

Table 7. Plant Factors for Established Landscape Plants, Turfgrasses, and Garden Crops to Provide Acceptable Performance in California[1] (UCANR, 2024).

Plant Type	Plant Factor
Tree, Shrubs, Vines, Groundcovers (woody plants)	0.5
Herbaceous Perennials	0.5
Desert Adapted Plants	0.3
Annual Flowers & Bedding Plants	0.8
General Turfgrass Lawns, cool-season (tall fescue, Ky. bluegrass, rye, bent)	0.8 [2, 3]
General Turfgrass Lawns, warm-season (Bermuda, zoysia, St. Augustine, buffalo)	0.6 [2, 3]
Home Fruit Crops, Deciduous	0.8 [2]
Home Fruit Crops, Evergreen	1.0
Home Vegetable Crops	1.0 [2]
Mixed Plantings	*PF of the planting is that of the plant type present with the highest PF*

[1] Values do not apply to nurseries, greenhouses, or other commercial farms.
[2] Plant Factors shown are the annual average K_c value.
[3] Plant factors do not apply to fields, golf greens, or trees.

Finally, the calculated water demand (ET) was divided by an assumed CUF (or irrigation efficiency) of 0.80 to estimate the annual applied water volume for irrigated landscaping areas.

c. Surface water bodies

In this TM, surface water bodies refer to either swimming pools or landscaping ponds that are not used for irrigation purposes (e.g., no inflows from or outflows for irrigation). Through coordination with growers, it was determined that all but one of landscaping ponds were lined (negligible seepage), and it was assumed that the final landscaping pond was also lined. It was also assumed that swimming pools had concrete bottoms (this assumption was confirmed through visual observations in the field whenever possible). Lastly, it was also determined through landowner coordination or assumed that there were no surface outlets (i.e., no surface outflows from surface water bodies). Therefore, the only water outflow was through evaporation and additional water was supplied to the water bodies to maintain constant water levels.

Similar to the estimation of irrigated landscapes, the SLIDE equation was also employed to estimate water demands, and subsequently, the water volumes required to maintain the surface water bodies. Cooperative Extension University of California (1994) recommended using a K_L correction factor of 1.1 for open water surfaces. The surface areas were estimated by delineating surface water body boundaries on Google Earth. It was also assumed that the water demand was equal to the water supply needed to maintain the water bodies (i.e., no losses, or an assumed CUF equal to 1.0).

3 Results

3.1 Estimating Mixed Purpose Water Volumes

There were a total of 20 properties included in the Study with water meters that measured water for multiple purposes, which included IUs consisting of irrigated agriculture nested within these properties. Of these, seven (35%) were excluded from this analysis, and subsequently, all other analyses and Study results due to a variety of reasons. These reasons included poor data records from water meters (e.g., likely malfunctioning or broken water meters) (n = 2), a lack of information to estimate water usage of commercial processing facilities (n = 2), landscaping ponds with relatively large estimated water usage relative to estimated irrigation of agriculture (n = 2), and a large presence of residences and shops with relatively large estimated indoor water usage relative to estimated irrigation of agriculture (n = 1). Ultimately, a total of 13 properties were included in this analysis to estimate applied water volumes for irrigated agriculture in 13 IUs.

Estimated water volumes for indoor uses, irrigated landscaping, surface water bodies, and irrigated agriculture are summarized in **Figure 13** and **Table 8**, expressed as a percentage of total water volumes.

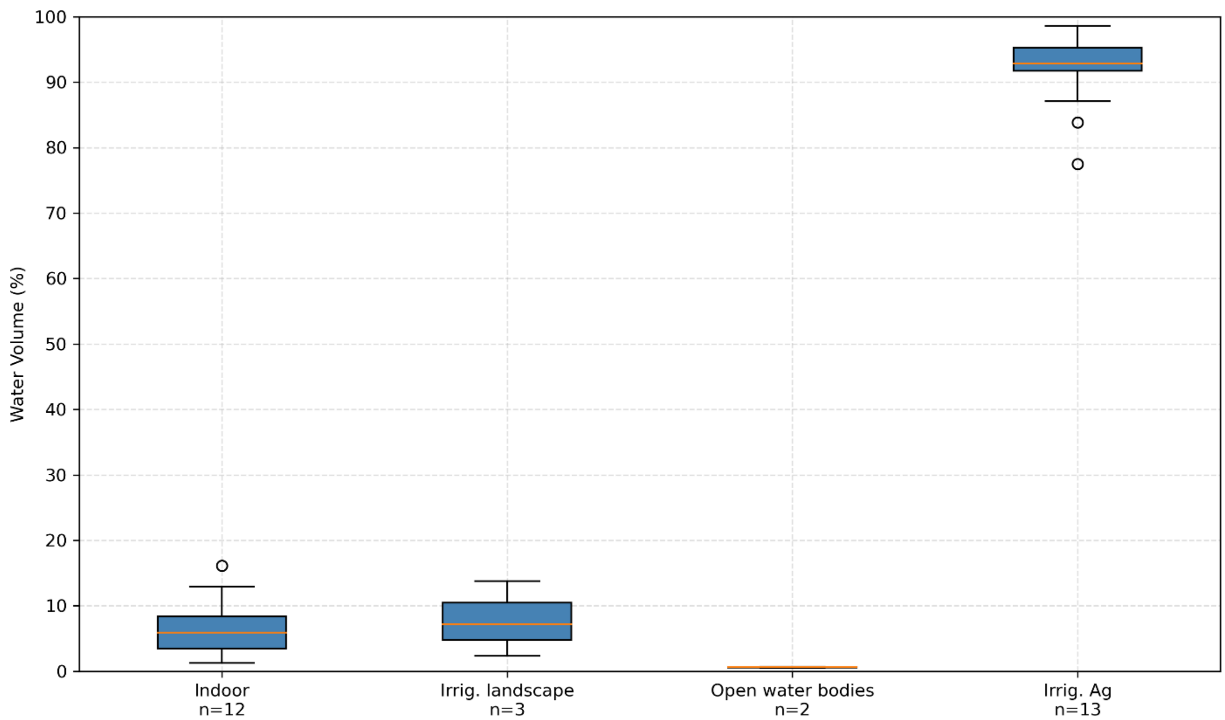

Figure 12. A box plot showing the distribution of water usage separated by indoor, irrigated landscape, open water bodies, and irrigated agriculture.

For these properties with multiple water consumption purposes, the maintenance of surface water bodies (n = 2; swimming pools) represented the smallest portion (i.e., < 0.7%) of estimated water consumption[2]. This was followed by indoor uses, which consumed a median of 5.9% of the total water consumption. Lastly, the irrigated landscapes were estimated to consume a median of 7.2% of the total water consumption. The IUs (i.e., irrigated agriculture) for these properties were estimated to consume a median of 92.9% of the total annual water consumption, with a range from 77.5% to 98.6%. The properties with only indoor usage generally had a larger proportion of water being used on irrigated agriculture, ranging from 83.9% to 98.6%. In contrast, while more limited, the properties with irrigated landscaping were estimated to have a relatively smaller proportion of water being used for irrigated agriculture. Notably, the lowest percentage for irrigated agriculture (78%) was observed at EDC_00014 due to above average indoor consumption and a large irrigated landscaping area.

Table 8. Summary of the total water consumption and estimated domestic consumption of each property.

Properties	Indoor consumption (%)	Irrigated landscapes consumption (%)	Open water bodies consumption (%)	IU with irrigated agriculture consumption (%)
EDC_00006	-	7.2%	-	92.8%
EDC_00007	1.3%	-	0.5%	98.2%
EDC_00008	12.9%	-	-	87.1%
EDC_00009	1.4%	-	-	98.6%
EDC_00011	6.9%	-	0.7%	92.4%
EDC_00012	8.3%	-	-	91.7%
EDC_00013	7.1%	-	-	92.9%
EDC_00014	8.7%	13.8%	-	77.5%
EDC_00015	4.9%	-	-	95.1%
EDC_00016	3.6%	-	-	96.4%
EDC_00017	16.1%	-	-	83.9%
EDC_00024	4.7%	-	-	95.3%
EDC_00026	3.3%	2.3%	-	94.4%
Number of IUs	12	3	2	13
Min	1.3%	2.3%	0.5%	77.5%
Median	5.9%	7.2%	0.6%	92.9%
Mean	6.6%	7.8%	0.6%	92.0%
Max	16.1%	13.8%	0.7%	98.6%

[2] As described above, the data for properties with landscaping ponds were excluded due to high estimated water use by ponds relative to irrigated agriculture and uncertainty about results.

4. Discussion and Conclusions

Overall, this effort used available data and reasonable assumptions to estimate for water volumes for purposes other than irrigation of agriculture. If there was higher uncertainty about data, assumptions, or results, these properties were excluded from this analysis and from the Study results. Seven of the 20 total properties (35%) were excluded. This effort allowed for quantification of the water volumes for the irrigation of agriculture only. The irrigated agriculture volume (%) presented in **Table 8** and estimated applied water percentages presented in Error! Reference source not found. were used to adjust water m eter volumes at applicable properties to provide a more accurate and complete dataset of applied water specifically for irrigated agriculture in the respective irrigation units for use in the Study report (DE, 2025).

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TECHNICAL MEMORANDUM

To: El Dorado Water Agency

From: Davids Engineering, Inc.

Date: March 31, 2025

Subject: **Summary of SSURGO Estimated and Field Verified Soil Data**

1 Introduction

Accurate soil property data are essential to root-zone modeling efforts that estimate agricultural water use, particularly evapotranspiration of applied water (ETAW). At Davids Engineering, the Soil Survey Geographic Database (SSURGO[1]) from the Natural Resource Conservation Service (NRCS) is routinely used to estimate field-scale soil characteristics for modeling purposes. SSURGO provides estimates of soil texture across the United States and associated physical properties using spatially-referenced soil map units. Soil map units are spatial representations of the dominant soil types within an area.

Although SSURGO is widely used for modeling applications, the inherent generalizations in the dataset raise questions about its accuracy at individual field scales. To evaluate the validity of SSURGO-derived estimates in the El Dorado Field Verification Study (Study) area, a field verification campaign was conducted. The purpose of this Study was to compare SSURGO soil texture estimates to laboratory-analyzed soil samples collected directly from agricultural fields. This technical memorandum (TM) presents the methodology used to collect and analyze soil samples (Section 2), the results of the comparison between SSURGO and field data (Section 3), and a discussion of key findings and their implications for modeling efforts (Section 4).

2 Methods

2.1 SSURGO Data Processing

Initial soil texture estimates were derived from the SSURGO dataset using NRCS-defined map units for irrigated fields in the Study area. Weighted averages of percent sand, silt, and clay for the top 0 to 10 inches of the soil profile were extracted for each field using the spatially represented map units provided by NRCS. These estimates served as the baseline for comparison with field-verified soil data.

2.2. Field Sampling and Laboratory Analysis

Soil samples were collected from 13 agricultural fields across the Study area, selected to represent a range of anticipated soil types and conditions. In each field, five samples were taken at depths between 8 to 12 inches below the soil surface using soil augers (Figure 13). Samples were composited by field, mixed thoroughly, and sent to the University of California (UC) Davis Analytical Laboratory[2] for particle

[1] More information about the Soil Survey Geographic Database (SSURGO) can be found here: https://www.nrcs.usda.gov/resources/data-and-reports/soil-survey-geographic-database-ssurgo.
[2] UC Davis analytical lab: https://anlab.ucdavis.edu/Pages/about

size analysis. Laboratory methods followed standard protocols to determine percentages of sand, silt, and clay, and final soil texture classifications.

Figure 13. Field soil sampling process. The left panel shows a DE team member using an auger to collect one soil sample in a field. The right panel shows the resulting soil sample separated based on depth.

3 Results

5.1 Percent Sand and Clay Comparisons

The mean absolute percent error (MAPE; Equation 1), which is a representation of the relative error between two methods, for percent sand content between UC Davis and SSURGO was 19.1% (Figure 8a). SSURGO estimates tended to have a low bias with a median percent difference (Equation 2) at 8.3%. On the other hand, the MAPE for percent clay between UC Davis and SSURGO was 33.6%, indicating more uncertainty between the UC Davis clay measurements and SSURGO estimates. SSURGO estimates of clay content also tended to have a high bias compared to UC Davis with a median percent error of -23.2%.

Equation 1: $Mean\ Absolute\ Percent\ Error\ (MAPE) = Mean\left(\left|\frac{UC\ Davis - SSURGO}{SSURGO}\right|\right) * 100\%$

Equation 2: $Percent\ Difference = \frac{UC\ Davis - SSURGO}{SSURGO} * 100\%$

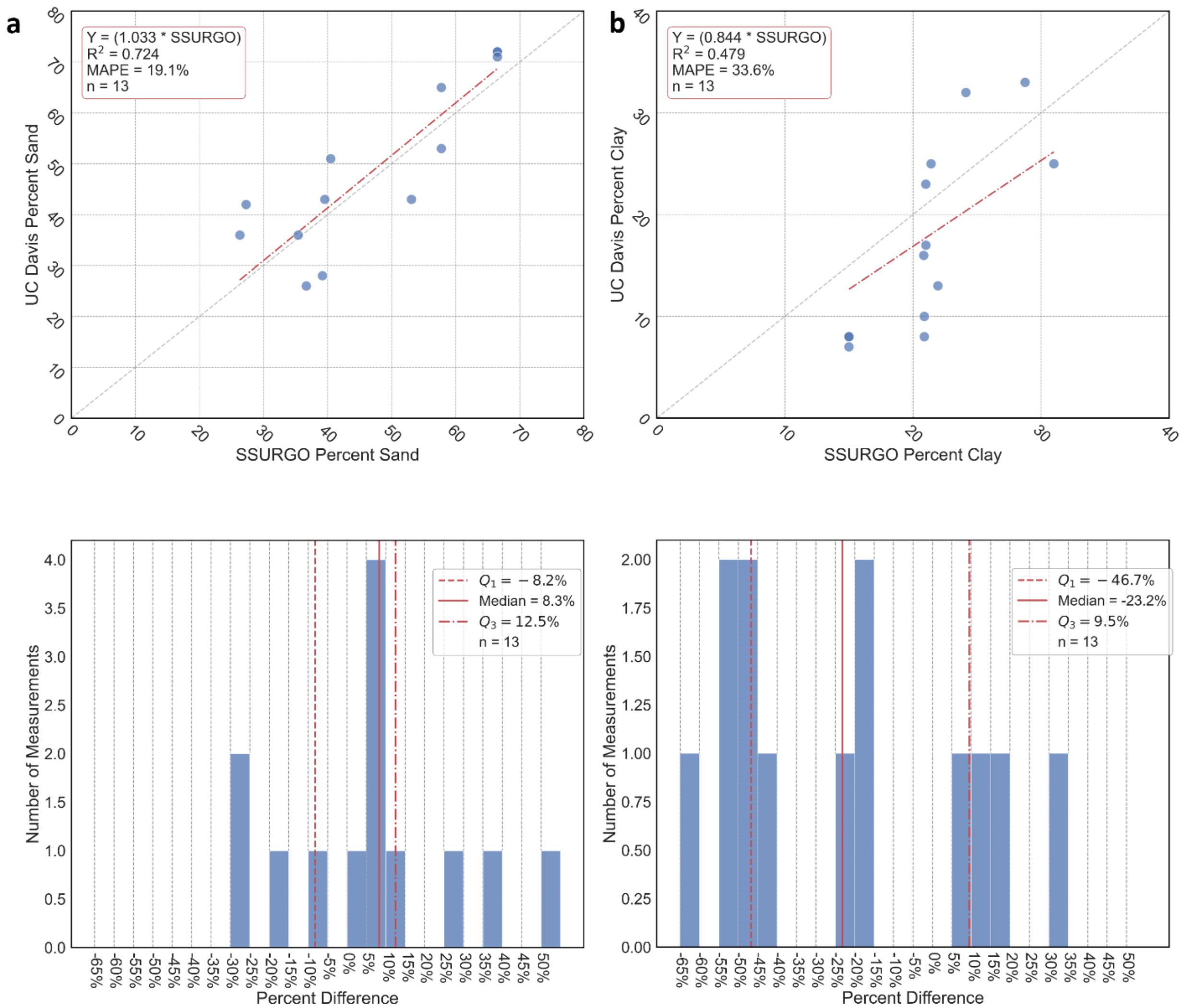

Figure 14. Comparisons between UC Davis measurements and SSURGO estimates of percent sand content (a) and percent clay content (b).

5.2 Overall Soil Texture

The overall soil textures, represented in Table 9, can be identified based on the percent sand and clay contents described above. Of the 13 fields, 6 (46%) had matching soil texture classifications between SSURGO and UC Davis lab results. For the fields in disagreement, SSURGO results tended to add clay modifiers to the overall soil texture compared to lab analyzed samples (e.g., Sand Clay Loam vs. Sandy Loam).

Table 9. Final soil texture comparisons between field soil samples analyzed in the UC Davis Analytical Lab (UC Davis) and data estimated using the Soil Survey Geographic Database (SSURGO).

Field ID	UC Davis	SSURGO
1	Sandy Loam	Sandy Loam
2	Sandy Loam	Sandy Loam

Field ID	UC Davis	SSURGO
3	Sandy Loam	Sandy Loam
4	Sandy Loam	Sandy Clay Loam
5	Sandy Loam	Sandy Clay Loam
6	Clay Loam	Loam
7	Loam	Sandy Clay Loam
8	Loam	Loam
9	Loam	Loam
10	Clay Loam	Clay Loam
11	Loam	Silt Loam
12	Clay Loam	Clay Loam
13	Loam	Silt Loam

6. Discussion and Conclusions

This analysis has a few limitations. First, field soils are generally heterogeneous, so sampling location can have a significant impact on the soil results obtained from the lab. While samples were pooled and aggregated at all field sites, five samples per field is a limited number of sampling locations compared to the acreage of most fields. Second, estimates from SSURGO are averaged between a depth of 0 to 10 inches within the soil profile while only one sample was taken between 8 to 12 inches in the field. The vertical averaging done by SSURGO may lead to additional differences compared to the field samples which were only taken in one depth.

Overall, with a few exceptions, the field-tested percentages of sand were within roughly 5-10 percent of the values from SSURGO data while the field percentages of clay were within roughly 20-30 percent. Overall, the soil textures generally aligned between the two methods (with the clay modifier noted above in three cases, and a silt modifier in two fields). These results generally indicate that the SSURGO data used in the model aligns reasonably well with conditions observed in the field, although the analysis has the limitations described above and was also limited in scope.