Water Demand Analysis

Date:	March 6, 2024
Project name:	Agricultural Water Resiliency Plan – Task Order No. 2
Project Number:	W7Y49500
Attention:	Colorado River Authority of Utah and Central Utah Water Conservancy District
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Executive Summary

This *Water Demand Analysis Technical Memorandum* (TM) summarizes the agricultural water demands in Utah's Colorado River Basin (CRB) and the Central Utah Water Conservancy District's (District's) service area. Subtask 2.2, Water Demand Analysis, includes seven activities in addition to preparing this TM. These activities aim to evaluate depletion estimates using remotely-sensed methods and compare results with currently available data from Utah's Division of Water Resources (UDWRe), Utah's Division of Water Rights (UDWRi), the Upper Colorado River Commission (UCRC), and the U.S. Bureau of Reclamation (Reclamation). In addition, estimated depletions were compared with the results of Subtask 2.1, Water Resource Inventory (Jacobs 2023a), to form a combined picture of future available agricultural water supplies against likely agricultural demands based on historical estimates.

Estimated remote sensing-based agricultural depletions across the study area (Utah's CRB and District service area lands) ranged from a minimum of approximately 886,000 acre-feet in 2018 to a maximum of approximately 1,158,000 acre-feet in 2020, across water years 2017 through 2020. Hay/turf fields, sprinkler-irrigated fields, and fields within Natural Resources Conservation Service's (NRCS') Land Capability Classifications (LCCs) 2 and 3 resulted in the highest depletion volumes when compared with fields of other crop types, irrigation methods, and LCCs.

Estimated remote sensing-based agricultural depletions in the Upper CRB (UCRB) ranged from 501,000 acre-feet in 2018 to 671,000 acre-feet in 2020, across water years 2017 through 2020. Remote sensing-based depletion results were compared with the UDWRe's Water Budget Model (WBM) results over the WBM period of record (1989 through 2020). Remotely-sensed depletions were lower than WBM results for water years 2017 through 2020 by an average of 13 percent.

Additional relevant data sources were investigated including UCRC's *Updated 2016 Upper Division States Depletion Demand Schedule* (depletion demand schedule; UCRC 2022), Reclamation's consumptive uses and losses for 2016-2020 (Reclamation 2022), and maximum potential depletion data provided by UDWRi. Although these data do not present an opportunity for direct comparison due to differences in intent and methodology, they do present additional context and are thus included and discussed.

Last, future water supplies available to agriculture in Utah's UCRB as modeled by the Colorado River Simulation System (CRSS) were compared with historical remote sensing-based and WBM depletion estimates for the UCRB. Results indicated that hydrologic shortages will likely lead to reductions in agricultural water depletions in dry water years. The average deficit when comparing 1989 through 2020 WBM depletion estimates with the CRSS driest year climate model predicted supply is 51 percent, although the wettest year scenario results in a 24 percent average surplus in supply when compared with the 1989 through 2020 WBM depletion estimates.

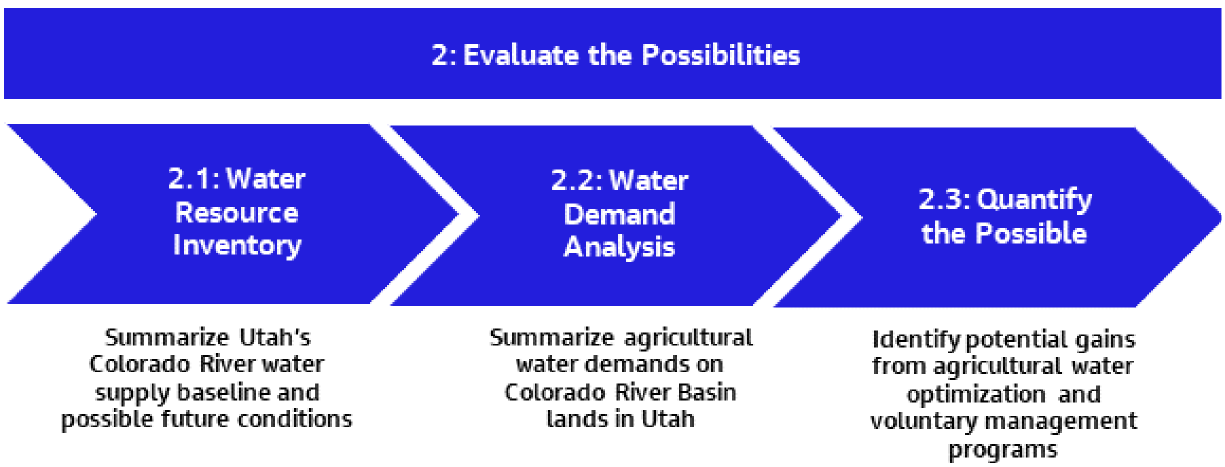
1. Objective

The objective of this Subtask 2.2, Water Demand Analysis, is to complete an inventory of agricultural water demands within the study area, which comprises CRB lands in Utah and District service area lands.

2. Introduction

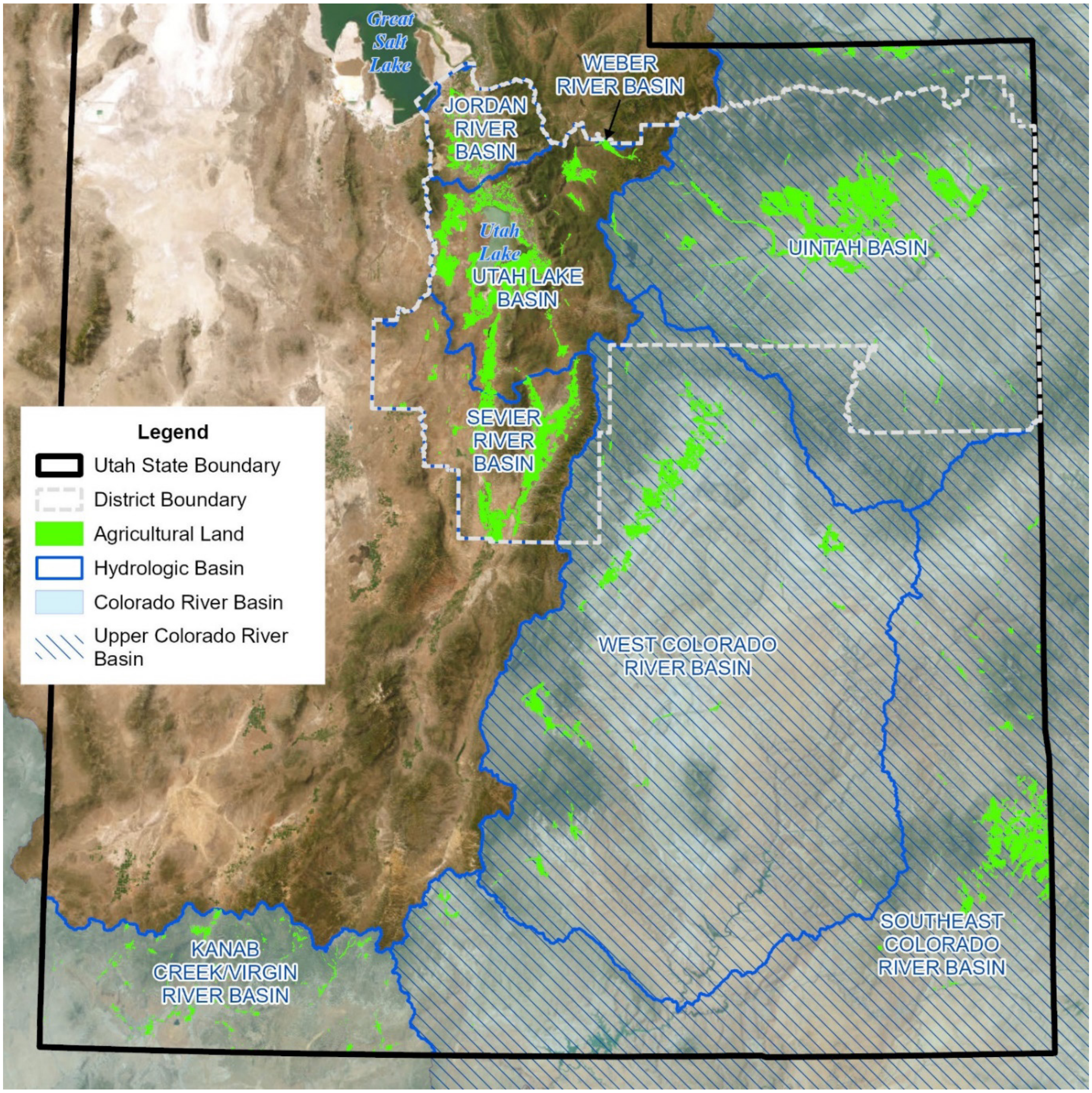
In February 2023, the District contracted Jacobs Engineering Group Inc. (Jacobs) to complete Task Order 2 of their Agriculture Water Resiliency Plan to meet both the District's and Colorado River Authority of Utah's (Authority) goal to evaluate potential programs, partnerships, outreach, and other efforts needed to make an investment in optimizing agricultural water use within the CRB lands in Utah. Task Order No. 2 was performed in part as an in-kind contribution to the Authority by the District due to complementary interests in Drought Mitigation Planning in the CRB. The Agriculture Water Resiliency Plan includes a key objective, Evaluate the Possibilities (Task 2), which includes the three subtasks identified on Figure 1.

Figure 1. Summary of Task 2, Evaluate the Possibilities, and Progression of Included Subtasks



The purpose of the three Task 2, Evaluate the Possibilities, subtasks is to evaluate the possibilities for reduced consumptive use in agriculture that promotes resiliency for both farmers and Utah's supply of Colorado River water. This evaluation was accomplished by analyzing available water supply, agricultural water demands, and potential gains from agricultural water optimization and voluntary demand management programs within the study area. The study area comprised CRB lands in the state of Utah and District service area lands; results were further delineated where appropriate by hydrologic basin. An overview of the CRB, District service area, included hydrologic basins, and all agricultural lands are illustrated on Figure 2.

Figure 2. Hydrologic Basins and Agricultural Lands in the Colorado River Basin and District's Service Area



This *Water Demand Analysis TM* documents the results of Subtask 2.2, including an inventory of agricultural water demands in the study area. The following subtask activities generally included in the project scope of work are covered in this TM:

1. In collaboration with OpenET and in accordance with UCRC (supported by Wilson Water Group) latest recommendations for calculating consumptive use from irrigation (CU_{irr})[1] estimates in the UCRB (WWG 2022), obtain field-scale eeMETRIC-based CU_{irr} estimates for Utah's CRB agricultural fields for all available years of data.

[1] For this analysis and TM, the terms CU_{irr} and *depletion* are equivalent.

2. Characterize eeMETRIC-based CU_{irr} in Utah's CRB by crop type, irrigation type, and land capability classification for all available years of data; intersect OpenET CU_{irr} data with publicly available datasets (UDWRe's Water Related Land Use [WRLU] and NRCS' LCC) in geographic information system (GIS) for characterization; and summarize statistical and map-based results.
3. Summarize study area agricultural depletions including remotely sensed (eeMETRIC) and WBM results
4. Obtain and summarize the maximum potential depletion of active water rights in the UDWRi Colorado River Water Rights Listing
5. Summarize Utah agricultural depletion and depletion demand in the UCRB using UCRC and Reclamation data sources
6. Compare depletion and depletion demand estimates across OpenET, WBM, UDWRi, and UCRC sources.
7. Summarize agricultural depletions in Utah's CRB using available datasets (including UDWRe WBM and OpenET eeMETRIC) to identify the range of depletion that occurs as a result of wet and dry years. Compare depletions with water supply results for the CRB obtained in Task 2.1, Water Resource Inventory.

3. Subtask Activities

3.1 Obtain Field-Scale Remote Sensing (eeMETRIC)-Based Depletion Estimates

In collaboration with OpenET and in accordance with UCRC's latest recommendations for calculating consumptive use of irrigation water (CU_{irr}) in the UCRB (WWG 2022), effective precipitation raster datasets were obtained for water years 2017 through 2020 from Desert Research Institute (Pearson pers. comm. 2023) and depletion calculated for agricultural fields[2] in the UCRB within Utah for each water year. For fields where an effective precipitation data value from DRI was available, depletion was calculated with Equation 1 in accordance with Appendix G of the Phase III report (DRI 2022 in WWG 2022), hereafter referred to as Method 1:

Equation 1:

Depletion (inches) = ET – Effective Precipitation **Method 1**

Where:

ET=eeMETRIC evapotranspiration (ET) (inches; Guzman pers. comm. 2023)
Effective precipitation = effective precipitation (inches)

For study area agricultural fields falling outside of the UCRB and fields in the UCRB not covered by the effective precipitation dataset supplied by the DRI,[3] a depletion method described in Hill (1989) was used to calculate water year depletion volume, hereafter referred to as Method 2. Carry-over soil moisture for each field was calculated using non-growing season (November through March) daily surface weather and climatological summaries (DAYMET) precipitation data (DAYMET 2023), the available water capacity for soils from the SSURGO database (NRCS 2023), and crop rooting depths (provided in Appendix B) (Lewis pers. comm. 2022). Equation 2 provides the depletion calculation considering carry-over soil moisture and 80 percent of precipitation considered effective, consistent with Hill (1989) as follows:

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[2] Agricultural fields identified in the respective year's WRLU dataset with crop type *dry crop* or description including *fallow*, *idle,* or *idle pasture* were omitted from this analysis. These fields are assumed to not receive irrigation water.

[3] Effective precipitation dataset raster coverage in the UCRB within Utah was investigated, and on average, 1.1 percent of fields by area were lacking an effective precipitation value across 2017 through 2020 datasets.

Equation 2:

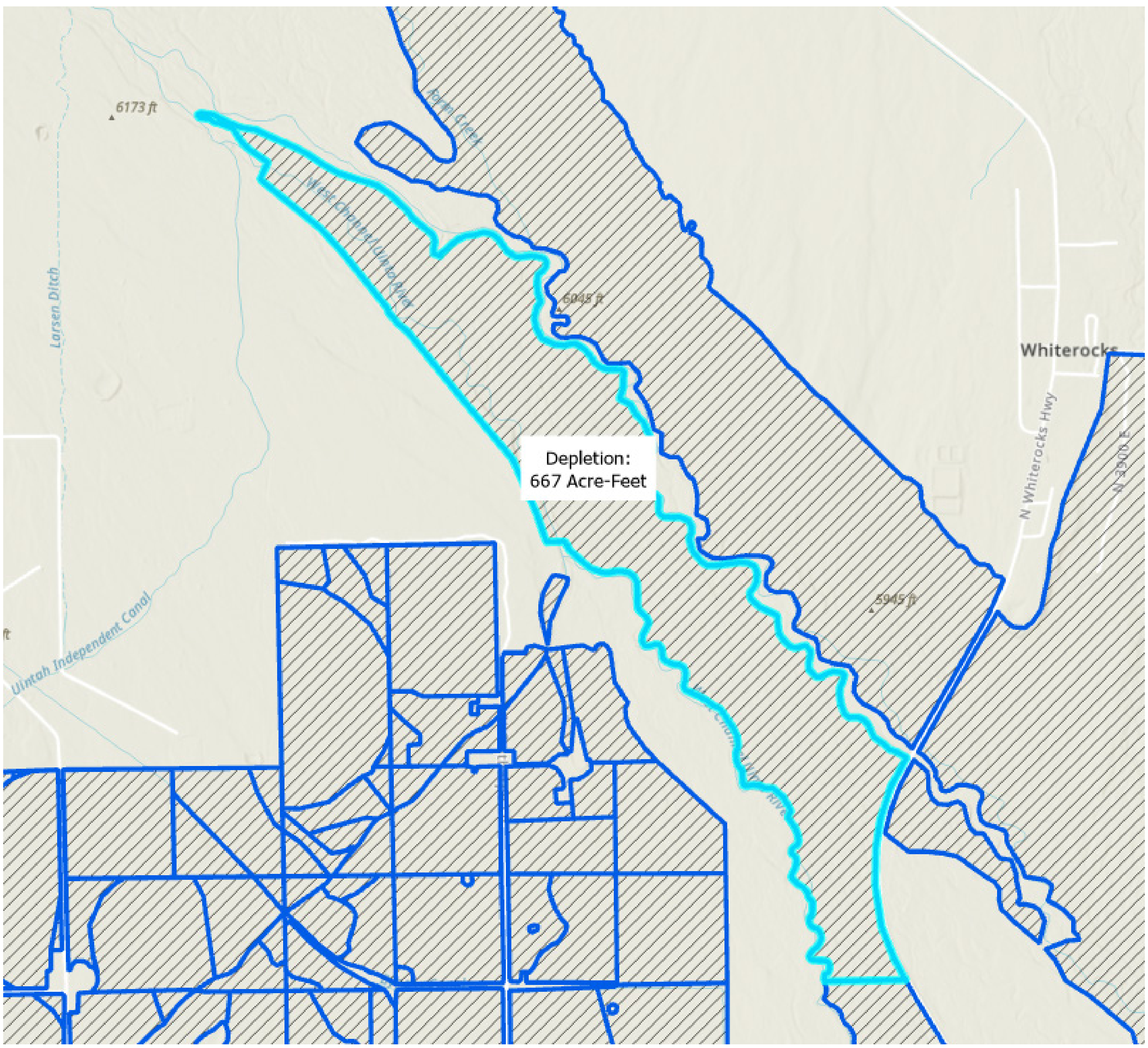
$$\text{Depletion (inches)} = ET - P_{eff} - SM_{co} \qquad \textbf{Method 2}$$

Where:

ET	=	eeMETRIC ET (inches)
P_{eff}	=	80 percent of DAYMET growing season precipitation (inches)
SM_{co}	=	carry-over soil moisture (inches)

The resulting depletion depths in inches were converted to a volume in acre-feet for each field by converting inches to feet and multiplying the depth by the field size in acres; the resulting water year depletions were joined with WRLU field identifiers to create a field-scale depletion model, identifying the depletion volume for each field included in the WRLU dataset for water years 2017 through 2020 (Figure 3).

Figure 3. Example of Depletion Joined to a 2020 Water Related Land Use Field



3.1.1 Compare Remote Sensing (eeMETRIC)-Based Depletion Estimates

The two remotely-sensed depletion estimation methods (refer to Methods 1 and 2) described in this section were compared to investigate their consistency with one another[4]. The RPD between results for a given field was calculated and variability investigated based on location and field size. The RPD computation used in this analysis is shown in Equation 3:

Equation 3:

$$RPD = \frac{|\text{Method 1} - \text{Method 2}|}{((\text{Method 1} + \text{Method 2}) \div 2)}$$

Where:

RPD	=	relative percent difference (decimal percentage)
Method 1	=	depletion calculated per Equation 1 (acre-feet)
Method 2	=	depletion calculated per Equation 2 (acre-feet)

The annual median RPD in 2017 through 2020 ranged from 8.1 percent to 10.9 percent with an average count of 29,144 fields in the UCRB. Figure 4 plots the 2017 through 2020 RPD results using box-and-whisker and density plots. These plots show an average RPD between approximately 6 percent and 10 percent, with the highest average RPD occurring in 2017 and the lowest in 2019. Year 2020 showed the tightest grouping of RPD values around the median on both the box-and-whisker and density plots. The density plot shows the distribution of RPD values by plotting the proportion of fields within each RPD range. All 2017 through 2020 density plots show a tight density distribution below 10 percent, with few fields exceeding 50 percent RPD. The RPD spikes at 200 percent occur where Method 1 predicts a depletion value of zero (effective precipitation exceeds eeMETRIC ET), while Method 2 predicts a depletion value greater than zero.

No discernable trend was seen in RPD variability based on field size, see Figure 5. This is to be expected since the pixel size[5] of precipitation data used in both depletion calculation methods far exceed the typical field sizes included in the 2017-2020 WRLU datasets and consistency across the two precipitation data sources is additionally expected.

As shown on Figure 6, a minor spatial trend of higher RPD values for fields located in the southern portions of Utah is visually apparent. This trend was additionally investigated through excluding the 200 percent RPD values, and similar trends of higher RPDs in more southern fields remained. One explanation of this spatial trend may be that Method 2, based on the *Field Verification of Empirical Methods for Estimating Depletion* report (Hill 1989), was developed for the Bear River watershed in Northern Utah and may have reduced accuracies as the field location moves south.

[4] Note that since the ET inputs into both methods was consistent, the comparison highlights differences in calculations of effective precipitation and carry-over soil moisture.

[5] Method 1 uses gridMET, available at a spatial resolution of 4km; Method 2 uses DAYMET, available at a 1km resolution.

Figure 4. 2017 through 2020 Relative Percent Difference Plots Comparing Methods 1 and 2 Formatted as Density Plots (A and C) and Box-and-Whisker Plot (B)

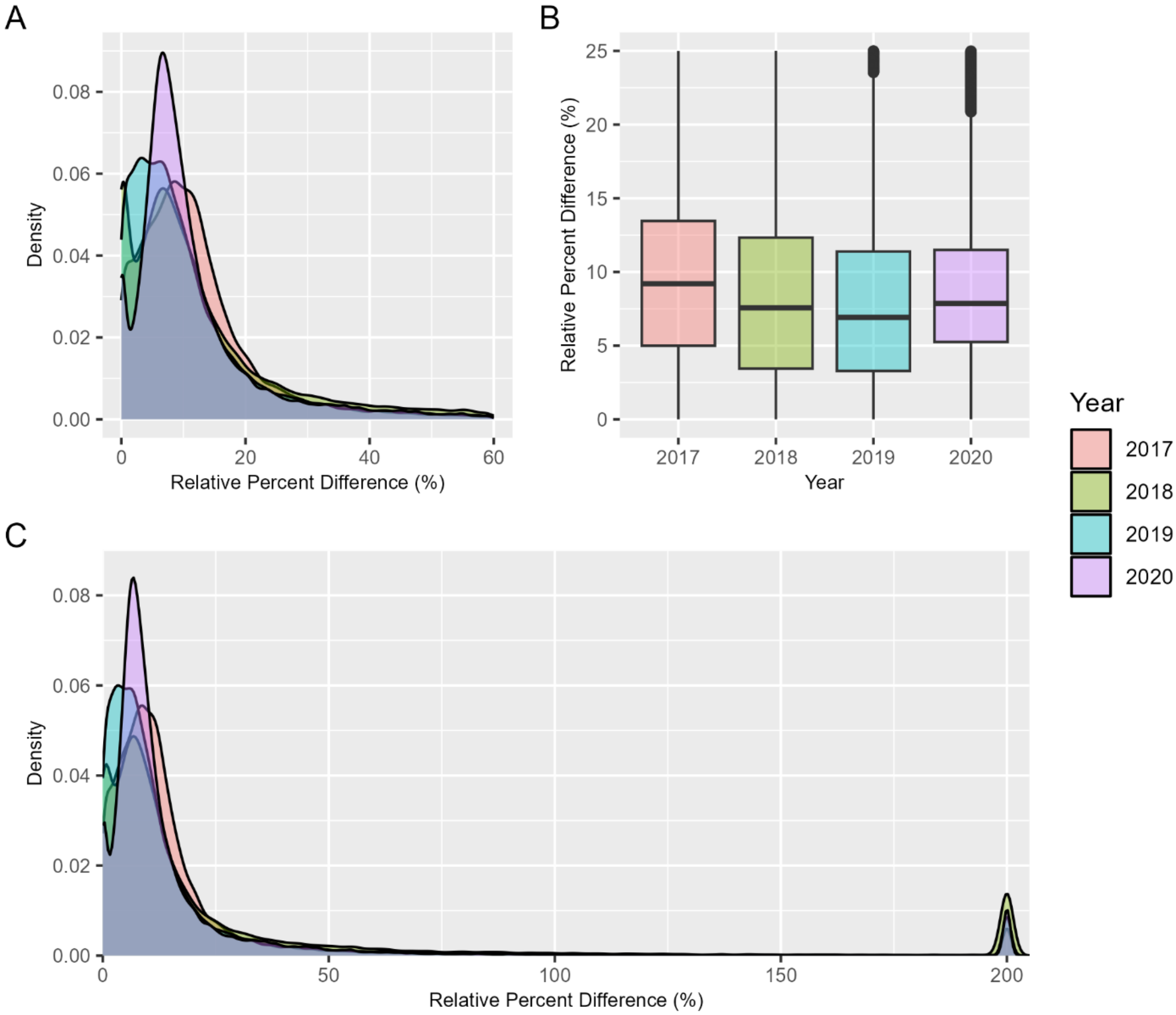
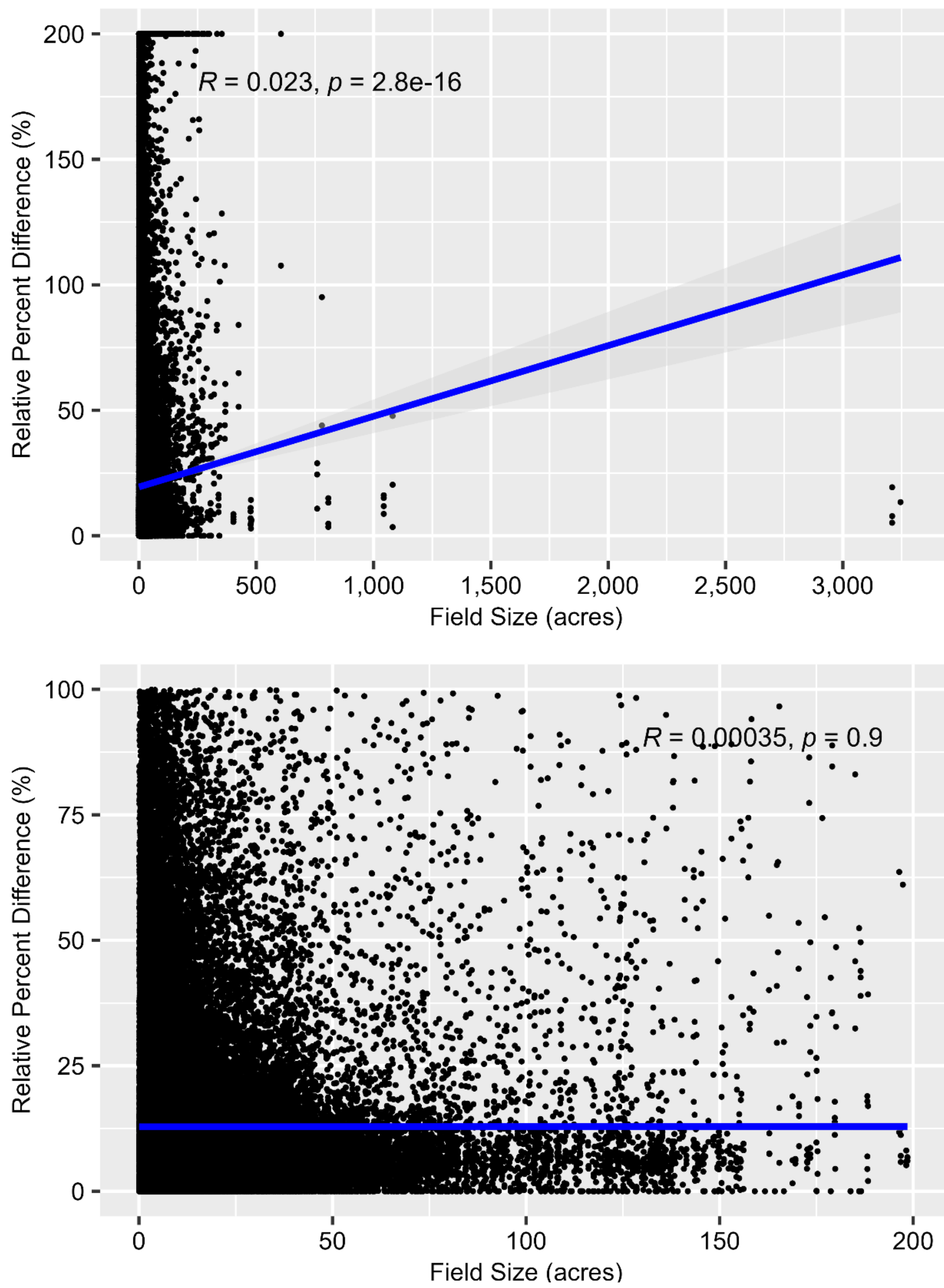
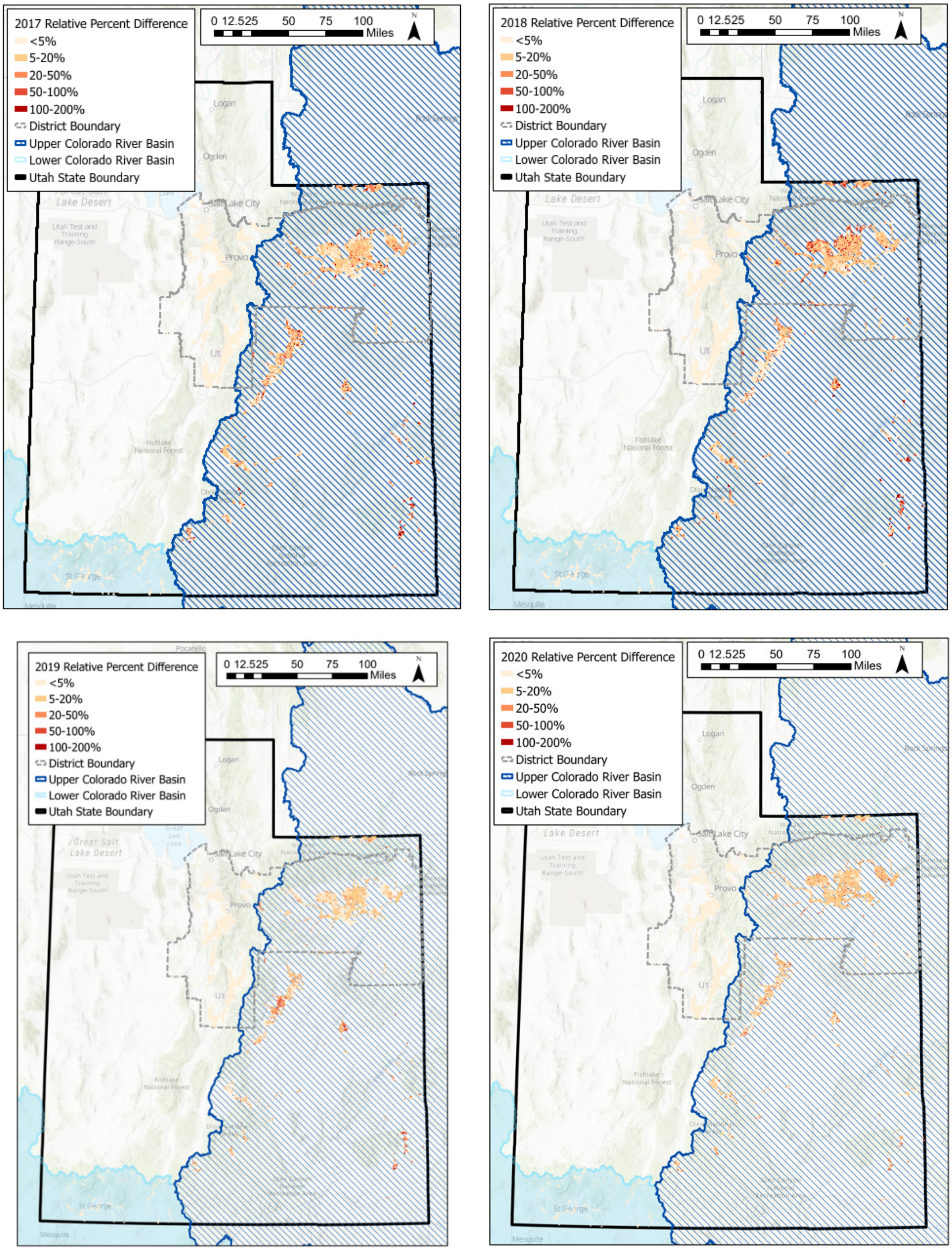


Figure 5. Relative Percent Difference Distribution Based on Field Size for All Fields in Utah (top) and Fields in Utah with a Total Area Fewer Than 200 Acres (bottom)



Note: The correlation coefficient (R) and statistical significance (p) values shown on the scatter plots measure linear association. R measures the strength of the linear relationship between field size and RPD. Generally, an R value greater than 0.7 is strong, while a value less than 0.3 is very weak. The p value shows the probability that there is no relationship between field size and RPD. A high p value, such as that when field size is limited to 200 acres (p=0.9), indicates a high probability that the relationship between field size and RPD is nonexistent. The p value in the full plot, including all field sizes, is likely influenced by the presence of outliers in the dataset, although the R value is still low on this plot. Both the R and p values in the lower plot on Figure 5 indicate that the correlation between field size and RPD is weak.

Figure 6. Spatial Distribution of Relative Percent Difference between OpenET and Hill Depletion Estimates in 2017 (top left), 2018 (top right), 2019 (bottom left), and 2020 (bottom right)



3.1.2 Summarize Remote Sensing (eeMETRIC)-Based Depletion Estimates

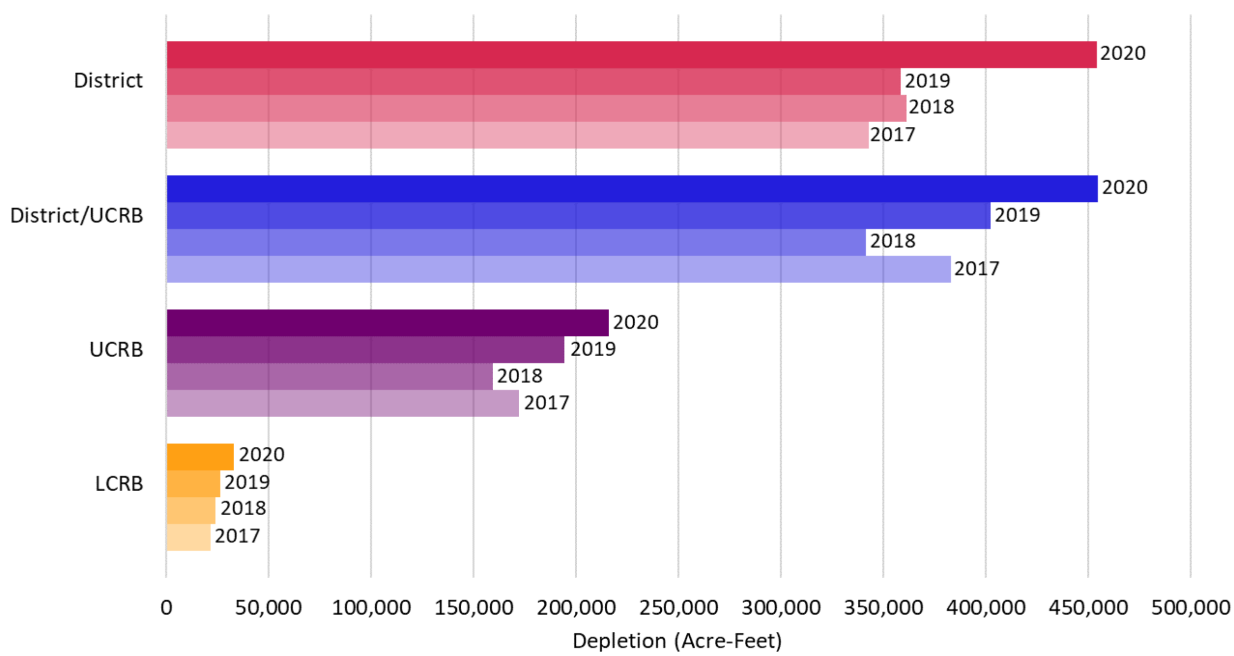
The total depletion volumes estimated with remotely-sensed methods—Method 1 (where possible) and 2 (elsewhere) —using eeMETRIC data from 2017 to 2020 ranged from a minimum of 886,000 acre-feet in 2018 to a maximum of 1,158,173 acre-feet in 2020[6] (shown in Table 1).

Table 1. Summary of 2017 through 2020 Depletion by Interest Area Using Remotely-Sensed Methods 1 and 2

Interest Area	Depletion (acre-feet)			
	2017	2018	2019	2020
District	343,024	361,217	358,736	454,520
District and UCRB	383,355	341,637	402,403	454,755
UCRB	172,357	159,225	194,309	215,898
LCRB	21,532	24,223	26,380	33,000
Total	920,267	886,302	981,828	1,158,173

Most of this depletion was computed in the District and the UCRB which was to be expected because very little of the state falls within the Lower CRB (LCRB). Figure 7 shows the depletion distribution from 2017 through 2020 broken out by Interest Area[7] and Figure 8 shows this depletion distribution spatially and includes a calculated depletion per acre for each Interest Area, which is simply the total depletion divided by the total field acreage investigated for each Interest Area. Depletion per acre may be impacted by irrigation methods, crop choices, and other factors. Appendix A provides additional information, including number of acres analyzed for each year from 2017 through 2020 and the associated depletion per acre.

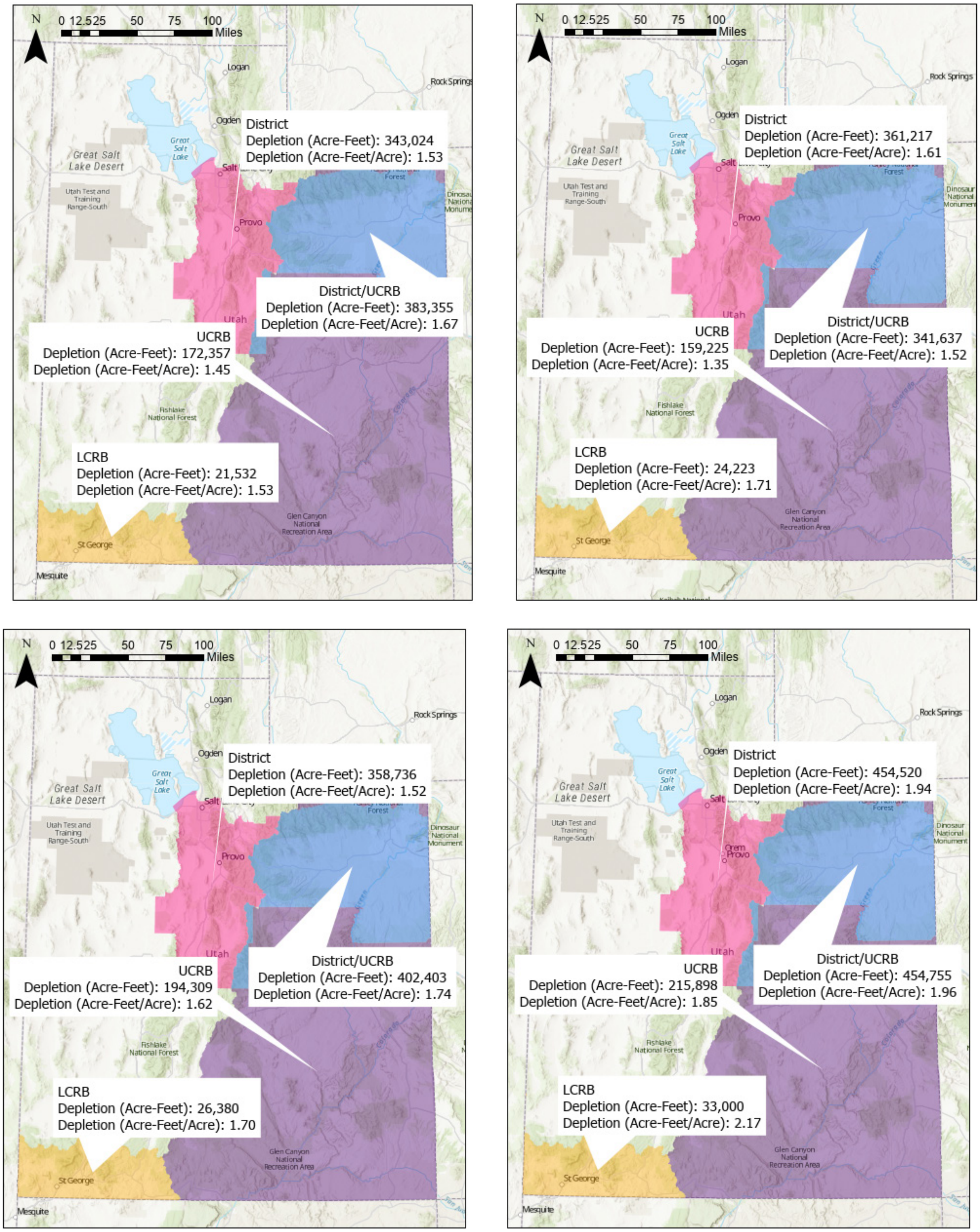
Figure 7. Total Depletion in 2017 through 2020 by Interest Area



[6] For fields where an effective precipitation data value from DRI was available, depletion was calculated using Method 1.

[7] Interest areas include District lands outside of the CRB (District), District lands inside the CRB (District/CRB), UCRB lands outside the District (UCRB), and LCRB lands outside the District (LCRB).

Figure 8. Total Depletion for 2017 (top left), 2018 (top right), 2019 (bottom left), and 2020 (bottom right)



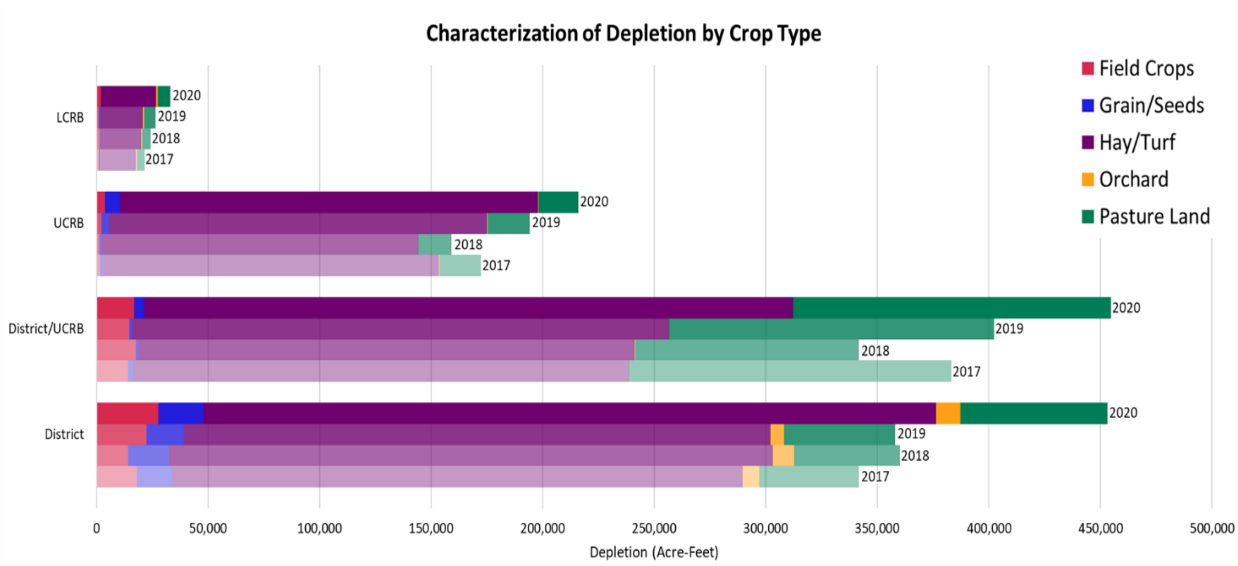
3.2 Characterize Remote Sensing (eeMETRIC)-Based Depletion Estimates

Joining the remote sensing-based depletion estimates provided in Section 3 with UDWRe's WRLU layer and NRCS' LCC in GIS allows depletion to be classified by crop type, irrigation type, and land capability class. These classifications were determined for water years 2017 through 2020, those years where effective precipitation datasets were available (Pearson pers. comm. 2023). Consistent with UDWRe's WBM results, depletion calculations include all field boundaries identified with an agricultural land use category in the WRLU dataset, excluding field boundaries classified as *dry crop* in the *Irrigation Methods* column and *dry land/other*, *fallow*, *idle*, and *idle pasture* from the *Description* column of the data. Overall, hay/turf fields, sprinkler-irrigated fields, and fields within LCC Classes 2 and 3 result in the highest depletion volumes when compared with fields of other crop types, irrigation methods, and LCCs.

3.2.1 Crop Type Classification

Characterized remote sensing-based depletion estimates by crop type shows hay/turf [includes alfalfa, grass hay, and turfgrass (sod farms)] as the major source of agricultural water demand across both the District's lands and the CRB (refer to Figure 9). The total depletion in fields of hay/turf accounts for more than 70 percent of the depletion in nonfallow or nonidle lands in the study area, both on an overall volumetric basis and on a volume per field area basis.

Figure 9. eeMETRIC Based Depletion Estimates from 2017 through 2020 Characterized by Crop Type



Notes:
The magnitude of depletion among garden and small fruit crop types was so little it did not appear on the chart. Depletion in acre-feet for garden and small fruit crop types were as follows:

- *Garden: 1,465 (2017), 1,298 (2018), 901 (2019), and 1,368 (2020)*
- *Small fruit: 79 (2017), 73 (2018), 68 (2019), and 66 (2020)*

Field Crops include: beans, corn, melon, onion, potato, pumpkins, sorghum, watermelon

Hay/turf is the highest consumptive crop both by a total depletion estimate and a depletion per acre basis as shown in Table 2 and Table 3, respectively. Pasture land follows hay/turf in depletion volume and results in approximately five times the total depletion as field crops in the average year; however, on a per acre basis, depletion on field crop agricultural lands is about 15 percent higher than pasture lands.

Table 2. Total and Average Depletion Estimates across Study Area by Crop Type for Water Years 2017 through 2020

Crop Type	2017	2018	2019	2020	Average
	(acre-feet)				
Hay/turf	644,920	653,101	691,810	831,728	705,390
Pasture land	211,278	166,019	219,453	231,707	207,115
Field crops	34,820	34,487	40,296	50,335	39,984
Grain/seeds	19,605	20,929	22,261	30,978	23,443
Orchard	8,101	10,394	7,039	11,991	9,381
Garden	1,465	1,298	901	1,368	1,258
Small fruit	79	73	68	66	71

Table 3. Depletion per Acre Averaged across Study Area by Crop Type for Water Years 2017 through 2020

Crop Type	2017	2018	2019	2020	Average
	(acre-feet)				
Hay/turf	1.72	1.71	1.79	2.15	1.84
Field crops	1.35	1.64	1.48	1.98	1.61
Orchard	1.24	1.59	1.03	1.71	1.39
Pasture land	1.34	1.10	1.35	1.48	1.32
Garden	1.33	1.26	0.98	1.56	1.28
Grain/seeds	1.00	1.07	1.16	1.53	1.19
Small fruit	0.91	0.84	0.73	0.71	0.80

3.2.2 Irrigation Type Classification

Sprinkler-irrigated fields resulted in the highest total depletion volume within the District and CRB fields in the 2017 through 2020 water years investigated, including methods of subirrigation, sprinkler, flood (surface), and drip (shown on Figure10 and in Table 4). Approximately one-half of the investigated fields within the study area are sprinkler-irrigated, and approximately one-third of the fields are flood (surface)-irrigated. In addition to being the two leading irrigation methods in depletion volume and area, sprinkler and flood (surface) irrigated fields result in the highest and second-highest depletion per acre, respectively, out of the four methods evaluated (shown in Table 5).

Figure 10. eeMETRIC-Based Depletion Estimates from 2017 through 2020 Characterized by Irrigation Method

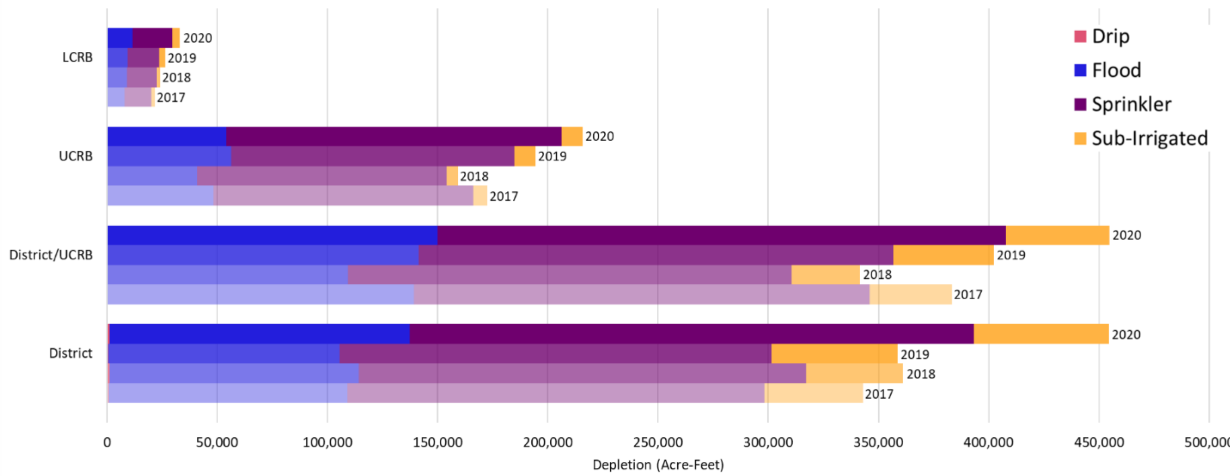


Table 4. Total and Average Depletion Estimates across Study Area by Irrigation Method for Water Years 2017 through 2020

Irrigation Method	2017	2018	2019	2020	Average
	(acre-feet)				
Sprinkler	525,791	530,997	553,970	684,484	573,810
Flood (Surface)	303,600	271,921	311,604	351,267	309,598
Subirrigated	89,894	82,044	115,414	121,034	102,097
Drip	982	1,341	840	1,387	1,137

Table 5. Depletion per Acre Averaged across Study Area by Irrigation Method for Water Years 2017 through 2020

Irrigation Method	2017	2018	2019	2020	Average
	(acre-feet/acre)				
Sprinkler	1.66	1.68	1.73	2.11	1.80
Flood (Surface)	1.49	1.36	1.53	1.80	1.55
Subirrigated	1.39	1.28	1.48	1.55	1.43
Drip	1.16	1.59	0.91	1.48	1.28

3.2.3 Land Capability Classification

The NRCS LCC shows soil suitability for most kinds of field crops. LCCs are grouped into the following eight numerical categories of generally decreasing soil suitability (USDA 2016):

- Class 1 soils have slight limitations that restrict their use.
- Class 2 soils have moderate limitations that restrict the choice of plants or that require moderate conservation practices.

- Class 3 soils have severe limitations that restrict the choice of plants or that require special conservation practices, or both.
- Class 4 soils have very severe limitations that restrict the choice of plants or that require very careful management, or both.
- Class 5 soils are subject to little or no erosion but have other limitations, impractical to remove, that restrict their use mainly to pasture, rangeland, forestland, or wildlife habitat.
- Class 6 soils have severe limitations that make them generally unsuitable for cultivation and that restrict their use mainly to pasture, rangeland, forestland, or wildlife habitat.
- Class 7 soils have very severe limitations that make them unsuitable for cultivation and that restrict their use mainly to grazing, forestland, or wildlife habitat.
- Class 8 soils and miscellaneous areas have limitations that preclude commercial plant production and that restrict their use to recreational purposes, wildlife habitat, watershed, or esthetic purposes.

Of special interest to the District and the Colorado River Authority of Utah are lands in the higher capability classifications since these are lands that are more well suited candidates for future demand management programs than the lower capability classes. In particular, Classes 6 and 7, have the least suitability for cultivation aside from Class 8 lands, which are precluded from commercial plant production. LCC Classes 6 and 7 comprise approximately 9 percent of the agricultural lands in the District and approximately 10 percent of the total depletion shown on Figure 11 and in Table 6. There is little variability observed in depletion on a per acre basis between the different land capability classes, as shown in Table 7.

Figure 11. eeMETRIC-Based Depletion Estimates from 2017 through 2020 Characterized by Land Capability Classification

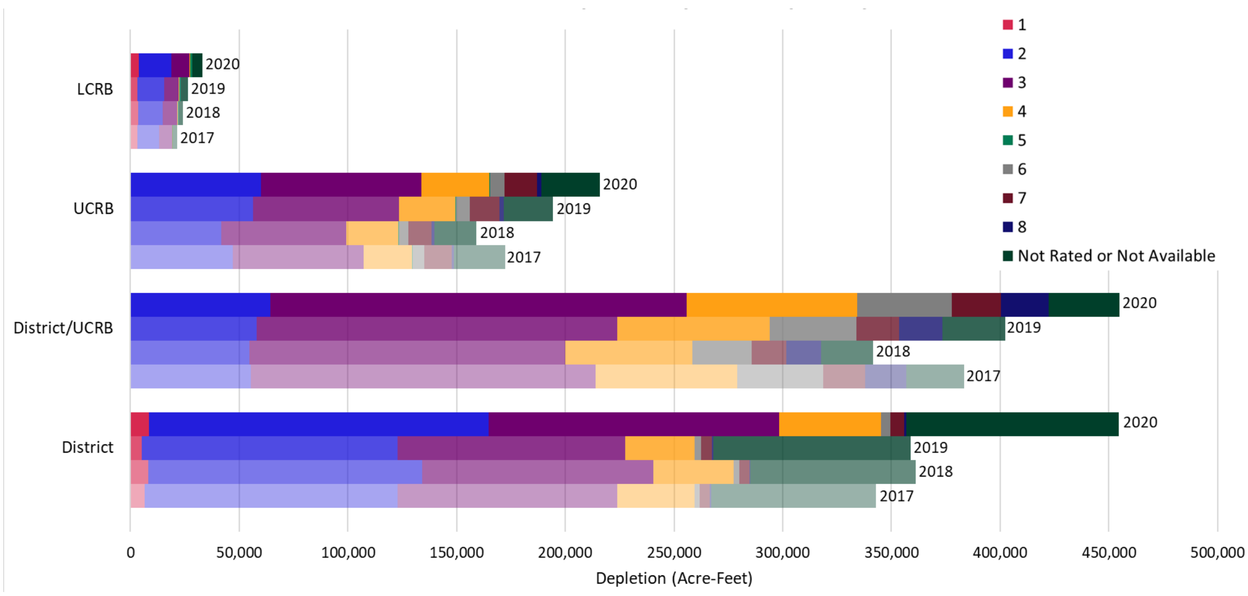


Table 6. Total and Average Depletion Estimates across Study Area by Land Capability Classification for Water Years 2017 through 2020

Land Capability Classification	2017	2018	2019	2020	Average
	(acre-feet)				
3	324,990	315,738	344,387	406,939	348,014
2	229,183	233,876	244,593	295,563	250,804
4	123,532	119,720	127,896	157,067	132,054
6	46,963	34,187	49,290	54,373	46,203
7	36,731	31,046	38,453	43,780	37,502
8	20,319	17,650	22,323	24,789	21,270
1	9,656	11,603	8,322	12,544	10,531
5	725	660	1,150	1,203	935

Table 7. Depletion per Acre Averaged across Study Area by Land Capability Classification for Water Years 2017 through 2020

Land Capability Classification	2017	2018	2019	2020	Average
	(acre-feet)				
2	1.61	1.68	1.69	2.07	1.76
8	1.65	1.43	1.77	1.97	1.70
3	1.60	1.57	1.66	1.99	1.70
6	1.66	1.21	1.71	1.90	1.62
1	1.41	1.79	1.28	1.96	1.61
4	1.49	1.46	1.52	1.86	1.58
5	1.50	1.44	1.62	1.77	1.58
7	1.52	1.29	1.54	1.76	1.53

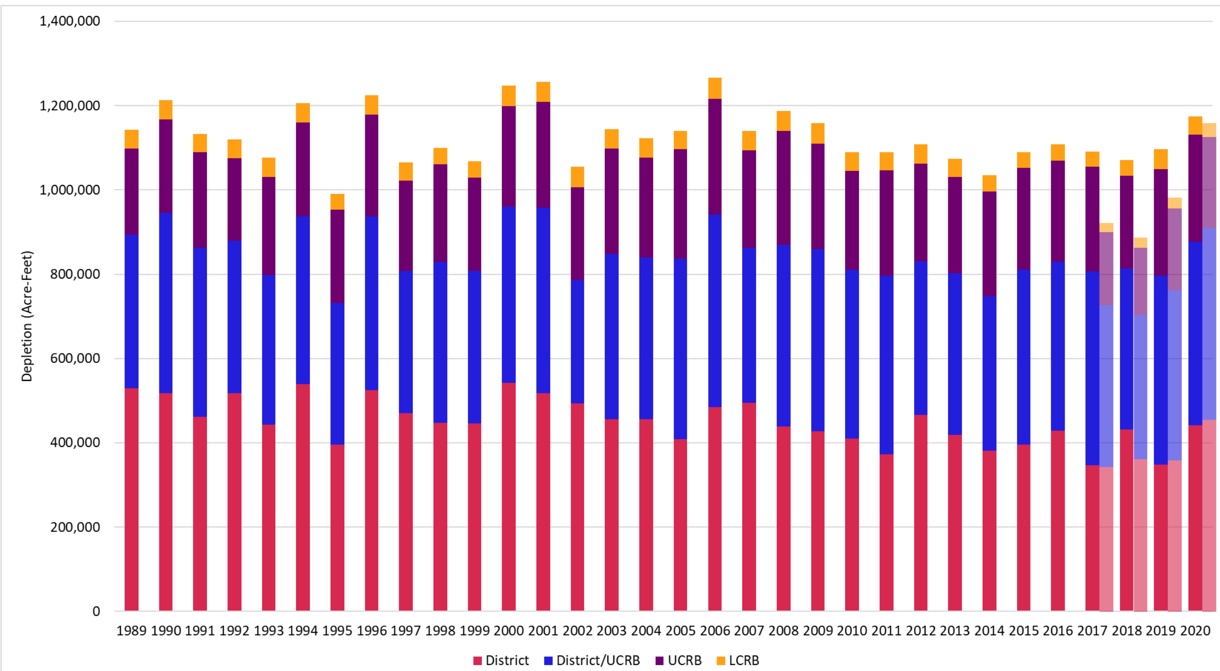
3.3 Summarize Study Area Agricultural Depletions - Remotely Sensed (eeMETRIC) and Water Budget Model

The remote sensing-based depletion estimates presented in Section 3.1 and available WBM results over the period of record are presented herein. Remote sensing-based depletion estimates using available effective precipitation datasets (Pearson pers. comm. 2023) were presented for water years 2017 through 2020. UDWRe's WBM results were obtained over their period of record from 1989 through 2020 (Ahmadi pers. comm. 2023).

The WBM depletion estimates provided include aggregated volumes by subarea. To compute WBM agricultural depletions for the study area, the native data provided by UDWRe were adjusted. For each subarea intersected by the study area boundary, a percentage of the total agricultural lands within the study area was calculated. Then, for each of these affected subareas, the total agricultural depletion volumes (in acre-feet) were multiplied by the percentage of agricultural lands in the study area. The resulting agricultural depletion volumes for each subarea were a proportion of the total volume based on the percentage of the subarea's agricultural lands in the study area. Although this approach is identified as a possible source of error in depletion estimates based on UDWRe WBM results, an analysis conducted as part of Task Order No. 1 (Jacobs 2023b) indicates the error is negligible.

Figure 12 illustrates WBM depletions across the period of record from 1989 through 2020 and the remote sensing-based depletions presented in Section 3.1 for water years 2017 through 2020 across the study area. WBM results exceeded the remote sensing-based estimates in 2017 through 2020 by an average of 13 percent; this result is expected because the remote sensing-based estimates using eeMETRIC ET data include satellite-driven calculations of *actual* ET, whereas the WBM results include an estimate of *potential* ET, using a gridded Penman Monteith methodology. Potential ET is the theoretical maximum amount of water that a well-watered crop could use under optimal growth and management conditions (WWG 2022). The eeMETRIC data include observed plant water stress and the impacts of drought and irrigation deficits and is, thus, considered an actual ET estimation method which are likely to be lower than potential ET estimations.

Figure 12. Depletion Estimates for 1989 through 2020 UDWRe Water Budget Model (dark) and 2017 through 2020 Remotely-Sensed eeMETRIC (light)



Further summarizing the data, Figure 12 illustrates WBM depletion estimates ranging from approximately 991,000 acre-feet to 1,266,000 acre-feet for the study area with a median depletion of approximately 1,114,000 acre-feet. WBM results indicate UCRB depletions ranging from approximately 512,000 acre-feet to 731,000 acre-feet with median depletion of approximately 631,000 acre-feet. The remote sensing-based depletion estimates ranged from approximately 886,000 acre-feet to 1,158,000 acre-feet with a median depletion of approximately 951,000 acre-feet for the study area. UCRB depletion estimates with remotely-sensed methods ranged from approximately 501,000 acre-feet to 671,000 acre-feet with a median depletion of approximately 576,000 acre-feet.

3.4 Obtain and Summarize Maximum Potential Agricultural Depletion – Active Water Rights in Utah's Upper Colorado River Basin

The UDWRi maintains an active list of all water rights, including both surface and groundwater rights, included in Utah's CRB. A water right list specific to the UCRB was obtained (Reese pers. comm. 2023) to compare maximum potential agricultural depletions with depletion estimates using remotely-sensed methods and other sources. The maximum potential depletion of water rights that include irrigation as a beneficial use in Utah's UCRB is approximately 2.0 million acre-feet. Notably, more than one beneficial use is often listed in a water right, so the maximum potential depletion volume reported includes uses other than irrigation, including domestic, mining, municipal, other, power, and stockwatering. Additionally, this value may be artificially inflated by double counting of supplemental water rights.

3.5 Summarize Utah Agricultural Depletion and Depletion Demand in the Upper Colorado River Basin – Upper Colorado River Commission and Bureau of Reclamation Sources

According to the UCRC depletion demand schedule (2022), future irrigation depletion demands in the UCRB within Utah were estimated to remain constant from 2020 through 2070 at 772,000 acre-feet. Utah's process for estimating agricultural demands found in the depletion demand schedule uses a gridded version of Penman-Monteith calibrated with local weather data that is incorporated into a statewide WBM, which models agricultural depletions based on an irrigation water requirement and other local conditions (UCRC 2024).

Provisional estimates of consumptive uses[8] for the Upper Colorado River Basin are published by Reclamation for calendar years 2016-2020 (Reclamation 2022). Agricultural irrigation consumptive use ranged from 662.7 kaf in 2016 to 796.1 kaf in 2020 (minimum and maximum respectively). Reclamation's methodology generally includes calculation of consumptive use rates for each major crop in each of the reporting years, subtraction of effective precipitation, applying results to irrigated acreage in the basin, and estimating water shortages [a more detailed discussion is included in Reclamation (2022)].

3.6 Compare Agricultural Depletion and Depletion Demand Estimates - Upper Colorado River Basin

Using the most current available data, depletion estimates in the UCRB are compared in Table 8, including the 2020 depletion estimate using remote-sensing based methods (based on OpenET's eeMETRIC ET data), 2020 depletion estimate using UDWRe's WBM data (Ahmadi pers. comm. 2023), 2020 agricultural depletion demand included in the depletion demand schedule (UCRC 2022), and UDWRi's current list of maximum potential depletion of water rights, which includes irrigation as a beneficial use in Utah's UCRB (Reese pers. comm. 2023).

The 2020 remote sensing-based depletion estimate and the estimate using 2020 WBM data are similar, with remote-sensing methods resulting in a slightly lower depletion volume of 670,653 acre-feet, compared with 690,595, a difference of 3 percent. UCRC's depletion demand schedule (2022) indicates a 2020 estimate for irrigation depletion demand of 772,000 acre-feet. This difference is expected because the depletion demand schedule includes all demands that may be fulfilled when ideal hydrologic conditions exist. The UDWRi maximum potential depletion value of 2.0 million acre-feet includes beneficial uses other than irrigation and, thus, results in a volume significantly higher than the other estimates and sources presented.

[8] The Bureau of Reclamation's use of the term *consumptive use* is synonymous with this report's use of the term *depletion*.

Table 8. Comparison of Agricultural Depletion Estimates and Depletion Demand across Remotely-Sensed, WBM, UCRC, and UDWRi Sources

Source	Agricultural Depletion and Depletion Demand in Utah's UCRB (acre-feet)
Remotely-sensed	670,653
WBM	690,595
UCRC	772,000[a]
UDWRi	2.0 million[b]

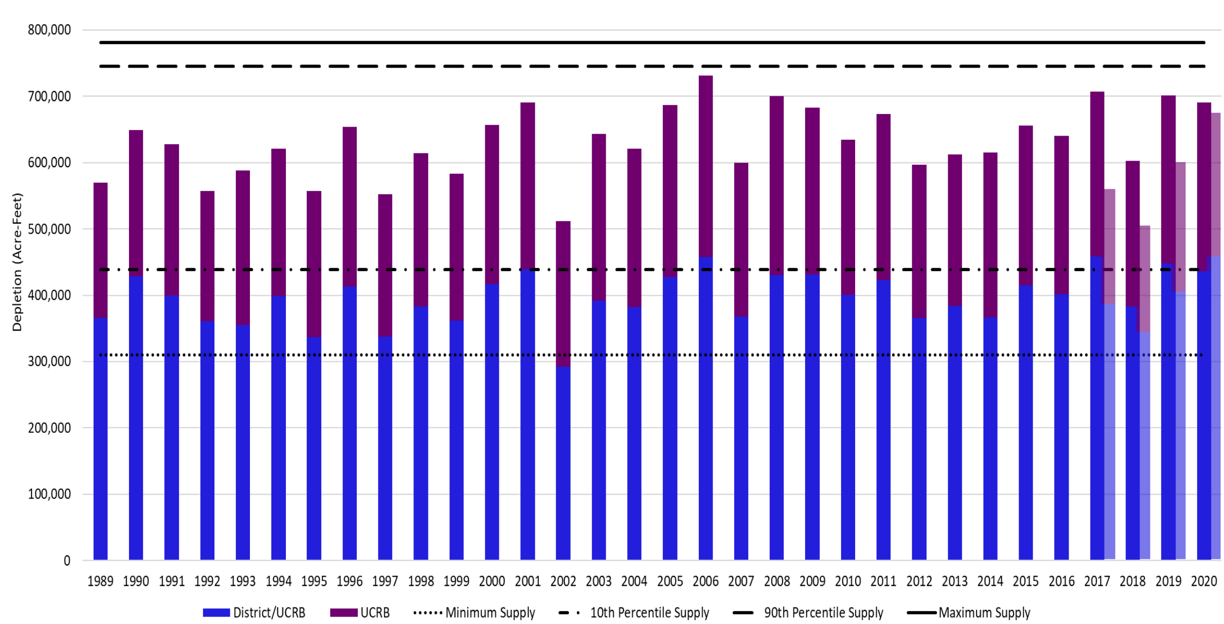
Note: Reclamation's consumptive use estimate for 2020 is intentionally omitted since the data included in Reclamation (2022) is based on the calendar year whereas estimates using remotely-sensed and WBM data are water year estimates.

[a] Agriculture – Irrigation & Stock depletion demand in accordance with UCRC depletion demand schedule (2022)
[b] This is the maximum potential depletion of active water rights in Utah's UCRB which includes irrigation as a beneficial use. More than one beneficial use is often listed in a water right, so the maximum potential depletion volume reported includes uses other than irrigation, including domestic, mining, municipal, other, power, and stockwatering. This value may be artificially inflated by double counting of supplemental water rights.

3.7 Summarize and Compare Agricultural Demand and Available Supply - Upper Colorado River Basin

The final activity of the Subtask 2.2, Water Demand Analysis, involved summarizing agricultural water demands against the total available supply presented in Subtask 2.1, Water Resource Inventory. Both WBM yield and CRSS results were presented across the study area in the Subtask 2.1 Water Resource Inventory TM (Jacobs 2023a). The most appropriate data for comparison with agricultural demands estimated herein are water supply data constrained to the UCRB and include the future estimated agricultural depletions sourced by UCRB water supply as modeled by CRSS. Figure 13 illustrates the range of future estimated agricultural depletions sourced by UCRB water supply with the minimum, 10th percentile, 90th percentile, and maximum depletion volumes provided.

Figure 13. Upper Colorado River Basin Depletion Estimates for 1989 through 2020 UDWRe Water Budget Model (dark) and 2017 through 2020 Remotely-Sensed eeMETRIC (light) Compared with Possible Future Agricultural Depletion under Upper Colorado River Basin Water Supply Scenarios



These estimates of future supply to agriculture were modeled in CRSS using the Coupled Model Intercomparison Project Phase 3 multimodal dataset (WCRP 2007). This modeled range of supply to agriculture has been applied over the estimated agricultural depletion results for the UCRB from both WBM and remotely-sensed methods on Figure 13.

A comparison of potential future agricultural depletions sourced by UCRB water supply modeled in CRSS and estimated agricultural depletions from WBM and remotely-sensed methods indicate future supplies are likely adequate to serve agricultural demands during wet years and hydrologic shortage will likely prevent historical depletions from being fulfilled in dry years. During wet years, the modeled (CRSS) potential agricultural depletions sourced by UCRB water supply shown with the solid black line exceed the estimated agricultural depletions from both WBM and remotely-sensed methods. This is expected since agricultural depletion demands modeled in CRSS are the full set of demands that may be observed under ideal hydrologic conditions. During dry years, the modeled (CRSS) potential agricultural depletions sourced by UCRB water supply shown with the dashed black line are lower than the estimated agricultural depletions from both WBM and remotely-sensed methods, indicating significant hydrologic shortage (tens to hundreds of thousands of acre feet) is likely to occur based on the model results presented.

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Appendix A
Supporting Data

Appendix A. Supporting Data

The area of agricultural lands in the study area from 2017 through 2020 ranged from 580,583 acres (2018) to 602,790 acres (2019), as shown in Table A-1. Agricultural fields identified in the respective year's Water Related Land Use dataset with crop type *dry crop* or description including *fallow*, *idle,* or *idle pasture*, were omitted from the analysis. Year-over-year changes in fallowed area, new agricultural lands development, and conversion of agricultural lands to other use types all contribute to the variability in agricultural area from 2017 through 2020.

Table A-1. Area of Agricultural Lands (acre) by Interest Area for Water Years 2017 through 2020

Interest Area[a]	2017	2018	2019	2020
District	223,844	223,851	236,140	234,283
District/CRB	229,402	224,975	231,200	231,520
Upper CRB	118,498	117,557	119,964	116,895
Lower CRB	14,112	14,200	15,486	15,174
Total	585,856	580,583	602,790	597,872

[a] Interest areas include District lands outside of the CRB (District), District lands inside the CRB (District/CRB), Upper CRB lands outside of the District (Upper CRB), and Lower CRB lands outside of the District (Lower CRB).

CRB = Colorado River Basin
District = Central Utah Water Conservancy District

Although total depletion volume and depletion per acre varies year-over-year, Table A-2 shows no discernible trend in this variation. Total depletion and depletion per acre were greatest in 2020 compared with 2017 through 2019.

Table A-2. Depletion (acre-feet) and Depletion per Acre by Interest Area for Water Years 2017 through 2020

Interest Area[a]	Depletion (acre-feet)				Depletion (acre-feet per acre)			
	2017	2018	2019	2020	2017	2018	2019	2020
District	343,024	361,217	358,736	454,520	1.53	1.61	1.52	1.94
District/CRB	383,355	341,637	402,403	454,755	1.67	1.52	1.74	1.96
Upper CRB	172,357	159,225	194,309	215,898	1.45	1.35	1.62	1.85
Lower CRB	21,532	24,223	26,380	33,000	1.53	1.71	1.70	2.17
Total	920,267	886,302	981,828	1,158,173	1.55	1.55	1.65	1.98

[a] Interest areas include District lands outside of the CRB (District), District lands inside the CRB (District/CRB), Upper CRB lands outside the District (Upper CRB), and Lower CRB lands outside the District (Lower CRB).

CRB = Colorado River Basin
District = Central Utah Water Conservancy District

Appendix B
Crop Rooting Depths

Table B-1. Crop Rooting Depths

Crop	Rooting Depth (inches)[a]
Alfalfa	54
Apples	42
Apricots	42
Barley	36
Beans	24
Berries	36
Cherries	42
Corn	36
Dry Land/Other	39
Fallow/Idle	39
Fallow	39
Field Crop unspecified	36
Grain/Seeds unspecified	36
Grapes	36
Grass Hay	24
Horticulture	24
Idle	39
Idle Pasture	39
Melon	60
Oats	36
Onion	30
Orchard unspecified	42
Pasture	39
Peaches	42
Potato	30
Pumpkins	60
Riparian	78
Rye	36
Safflower	36
Sorghum	36
Spring Wheat	36
Sunflower	48
Triticale	36
Turfgrass	24
Turfgrass Ag	24
Vegetables	24
Watermelons	60
Winter Wheat	36

[a] Crop rooting depth data includes data obtained from UDWRe (Lewis pers. comm. 2022) and assumptions made by Jacobs based on available data