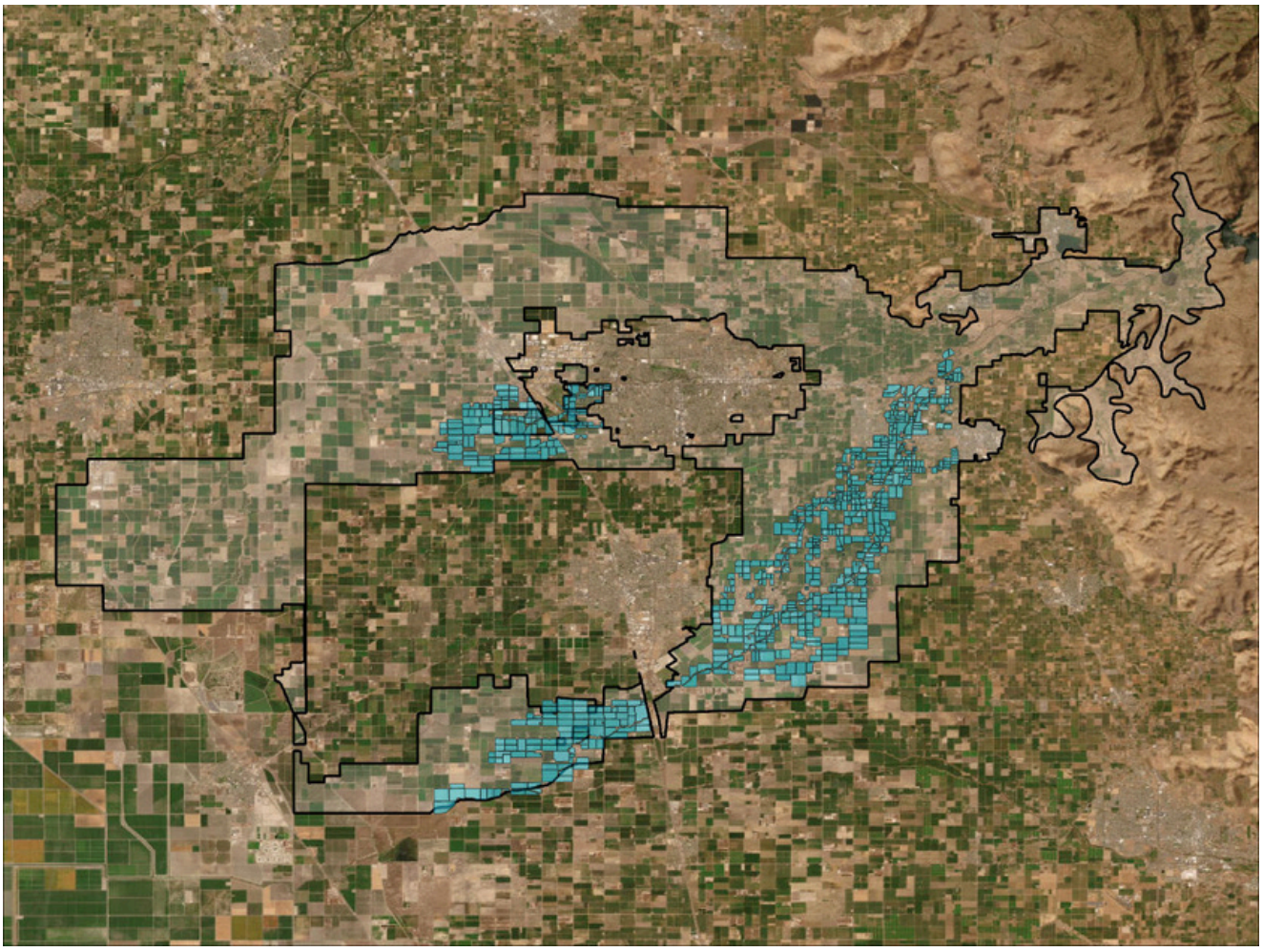
Technical Memorandum

June 30, 2026

To: California Department of Water Resources
Consolidated Water District

From: Sustainable Conservation
Earth Genome

RapidGRAT Assessment of Recharge Potential in Greater Kaweah Subbasin



Sustainable Conservation

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FROM:	Sustainable Conservation Earth Genome
SUBJECT:	RapidGRAT Assessment of Recharge Potential in Greater Kaweah Subbasin

Introduction

This technical memorandum describes the methodology used to estimate how much recharge is possible by the newly formed Consolidated Water District in the Greater Kaweah Groundwater Sustainability Agency (GSA) service area within the Kaweah subbasin. The Consolidated Water District serves approximately 80,000 acres of land with senior surface water rights from the Kaweah and St. Johns Rivers delivered by the Farmers Ditch Company, Consolidated Peoples Ditch Company, Persian and Watson Ditch Company, and the Elk Bayou Ditch Company. This project provides results for the Consolidated Water District but could easily be expanded throughout the GSA subbasin with additional information from local water districts. The methodology was developed as a template to inform evaluation of recharge potential for other groundwater basins throughout California. The methodology was derived from the Groundwater Recharge Assessment Tool (GRAT).

GRAT is a spatiotemporal optimization model that allows water managers to evaluate recharge strategies given a set of constraints (e.g., the fields that have access to surface water) and goals (e.g., improving water supply near a disadvantaged community). It has been deployed successfully in several regions of California's Central Valley including the Merced and Tuolumne River basins. However, the tool cannot be quickly scaled to other locations because it requires detailed and locally specific information to be deployed effectively. Moreover, GRAT requires developing a hydrologic model to estimate the expected frequency and volume of water available for recharge (WAFR), which takes time and expertise. The WAFR is an important data input for GRAT and among the constraints that GRAT considers in its optimization.

RapidGRAT emerged out of a need to provide a relatively quick estimation of recharge potential in various watersheds. Recharge potential, in a GRAT or RapidGRAT analysis, is the maximum amount of recharge possible to achieve in a region through canal seepage, recharge basins, and on-farm

recharge if availability of water were not limited. However, RapidGRAT simplifies the estimation as it does not require a WAFR input. Essentially, RapidGRAT assumes unlimited water is available for four consecutive months (December through March). It is the upper bound to what is possible for a recharge program to achieve if all growers with access to surface water actually applied that water for recharge at agronomically safe rates. Although rare, years like 2023 served as a reminder that winters with significant water supply do occur. The goal of this assessment is to inform districts and groundwater agencies what they are capable of accomplishing in such a year, so they can better plan and prepare. RapidGRAT can also help motivate farmers to participate in recharge programs by estimating the total water supply benefit to the groundwater basin that recharge could provide.

RapidGRAT Methodology

The following are the steps to reproduce a RapidGRAT for another region in California. Note that the datasets used and referenced below largely rely on California-centric sources, but could be adapted to other states and regions with the appropriate data sources.

1. **Download the most recent land use data from Land IQ**, an agricultural and remote sensing firm that has worked with the California Department of Water Resources (DWR) to map land cover throughout the State using remote sensing and on-the-ground measurements (Figure 1). In this assessment, the 2022 water year mapping was used. Then the Soil Agricultural Groundwater Banking Index (SAGBI), a soil suitability index for groundwater recharge from UC Davis (Figure 1), was used to determine each field's recharge suitability.

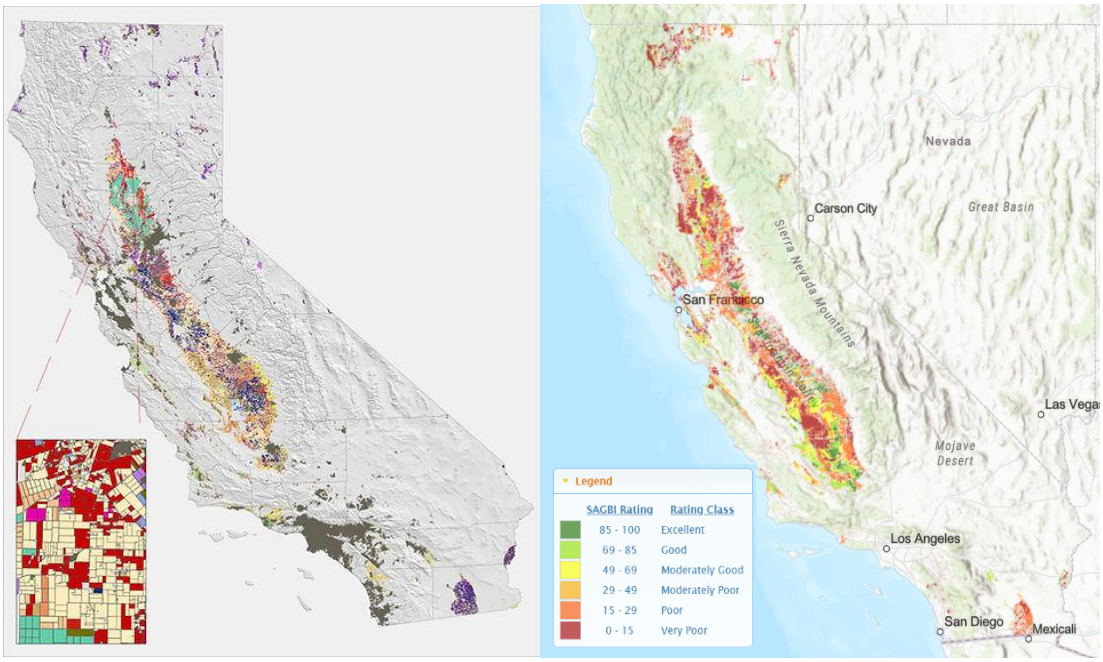


Figure 1. Land IQ-classified fields (left) and SAGBI-classified fields (right). Images from *https://www.landiq.com/land-use-mapping* and *https://casoilresource.lawr.ucdavis.edu/sagbi/*, respectively.

2. **Determine which fields are served by surface water conveyance** (Figure 2). The simple GIS boundary of the district service area (in black) was not sufficient, since not all fields inside are actually connected to the surface water conveyance network. It was crucial to work with district staff who have on-the-ground knowledge of the water delivery system. Six district staff members spent a total of 40 hours over two months preparing the dataset for this assessment. Helpfully, they also grouped the fields according to which canal they are served by, and provided data on where bottlenecks exist along the canal network and how much water could be conveyed at those points (provided as cubic feet per second, which was converted to acre-feet per month for the RapidGRAT analysis). These data were crucial for the constrained conveyance analysis (described in Step 4).

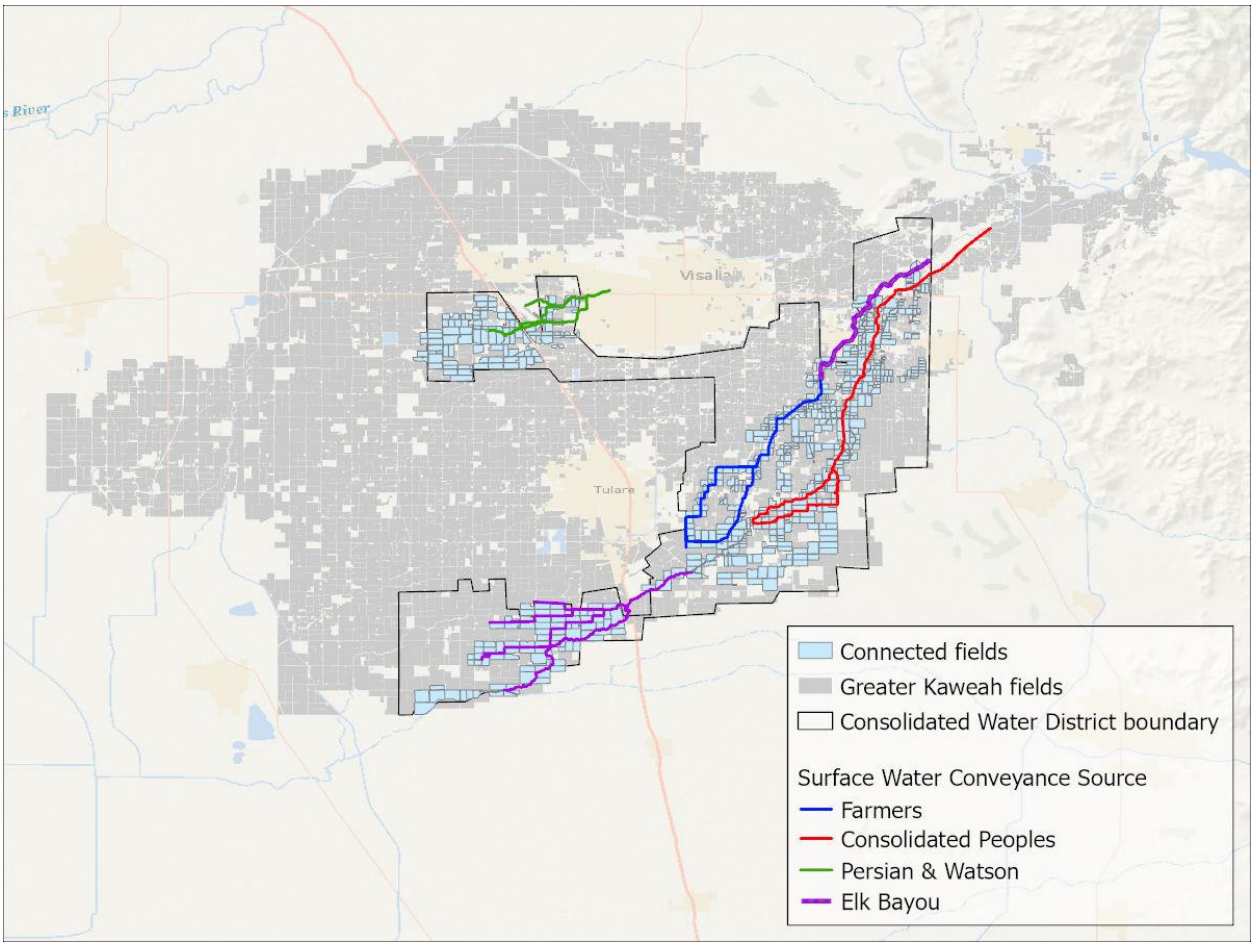


Figure 2. Fields in the Consolidated Water District (black boundary) served by surface water conveyance.

3. **Calculate recharge potential for each field** (Figure 3). GRAT's daily Crop Compatibility Calendar, which was developed using DWR's Integrated Water Flow Model Demand

Calculator, was used to determine the maximum volume of water that a field can recharge each month without harming crop health (Appendix A), based on its crop type and soil characteristics (i.e., SAGBI). For example, an almond orchard with moderately good soil can handle 1.68 acre-feet of recharge per acre in December without risking tree health, but only 1.05 acre-feet per acre in February. In March, recharge is not possible at all because high winds risk blowing over the trees if the soil is saturated. These crop- and soil-specific recharge rates were then multiplied by each field's acreage to calculate the field's recharge potential.

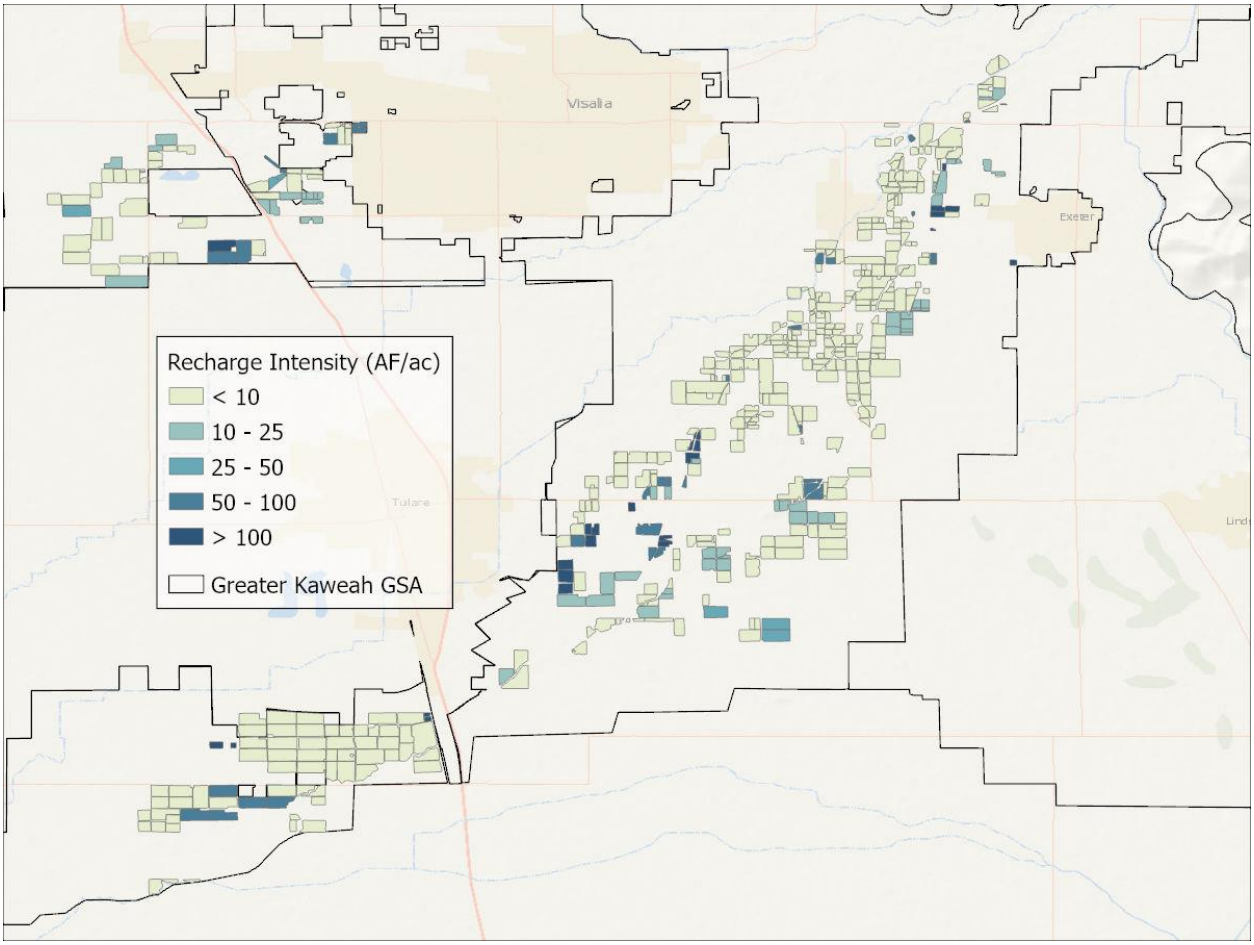


Figure 3. Annual recharge potential per field for all fields in the Consolidated Water District (unconstrained by the amount of water that can be delivered by the canals).

4. **Limit the number of recharge fields so that canal deliveries do not exceed canal capacity** (Figure 4). A script was written in Python to sum up all the water that can be applied on fields served by each canal each month, and if this is higher than the canal's monthly delivery capacity, the algorithm deletes fields, starting with the fields that recharged the least water, until the two totals match. This routine concentrates recharge in the smallest possible number of fields (those with the highest recharge potential), which reduces land footprint and labor costs.

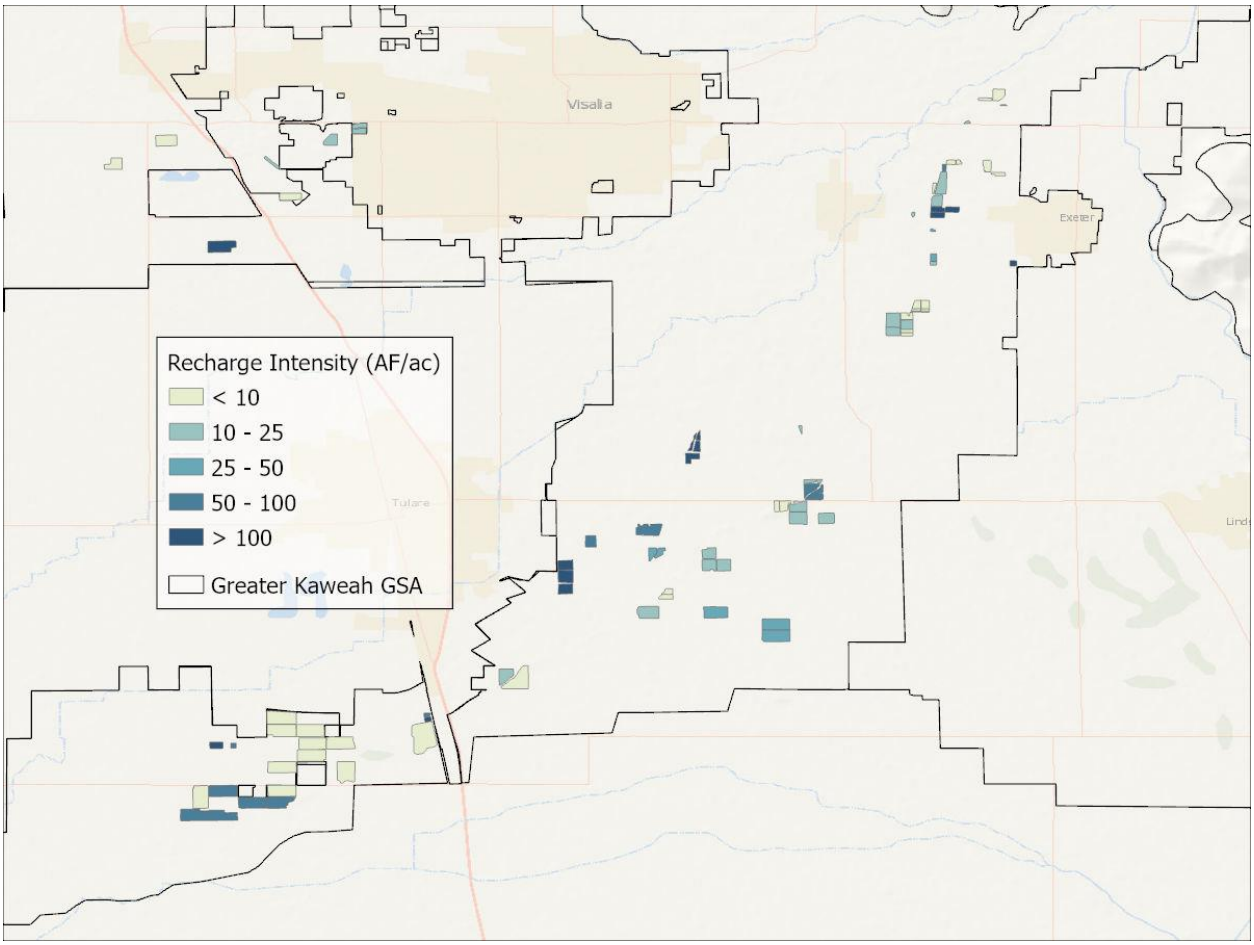


Figure 4. Annual recharge potential per field (constrained by canal capacity).

5. **Add basin recharge and canal seepage.** Multiplying each canal's total water delivery by its seepage rate gives us the volume of canal seepage. Basin recharge is calculated using each basin's maximum percolation rate and area. If basin recharge rates are not known, use the recharge rate for fallowed land and its predominant soil type (e.g., the recharge rate for fallow land with excellent soil is 1.5 acre-feet /acre/day). See Appendix A for monthly recharge rate data by land use and soil type.

RapidGRAT Results

Annual Recharge Potential

After calculating the recharge potential for each individual field, those values were summed to create the total recharge potential of the service areas, unconstrained by the amount of water the canals can deliver. This total unconstrained recharge potential was 330 thousand acre-feet (TAF) per year. However, the canal network of the Ditch Companies only has the capacity to deliver **208 TAF** (Table 1). For comparison, the average annual overdraft in the Greater Kaweah subbasin is 34.6 TAF. This suggests that the Consolidated Water District's existing canal capacity and available recharge acreage could offset the entire subbasin overdraft if unlimited water was available one

out of every six years. About 42% of that 208 TAF will seep through the bottom of the canals, providing 86 TAF of recharge. Another 24 TAF (11%) can be delivered to the eight recharge basins in the area. This leaves 98 TAF (47%) of the available water for on-farm recharge (Figure 5). In an ideal situation where the fields with the highest recharge potential are used, only **245 fields (7,372 acres)** need to participate in the program to recharge that volume (Figure 6).

Table 1. Capacities of the canal network of the Ditch Companies.

Ditch Company	Capacity (cubic feet per second)	Seepage	Max Delivery (acre-feet per month)
Farmers	300	60%	7,366
Persian	70	30%	3,008
Peoples + Elk	500	30%	21,483

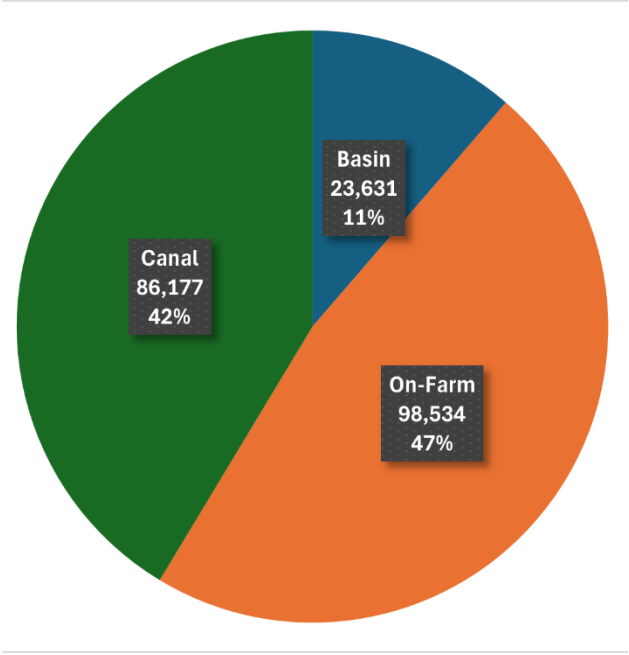


Figure 5. Annual recharge potential by recharge type, in AF.

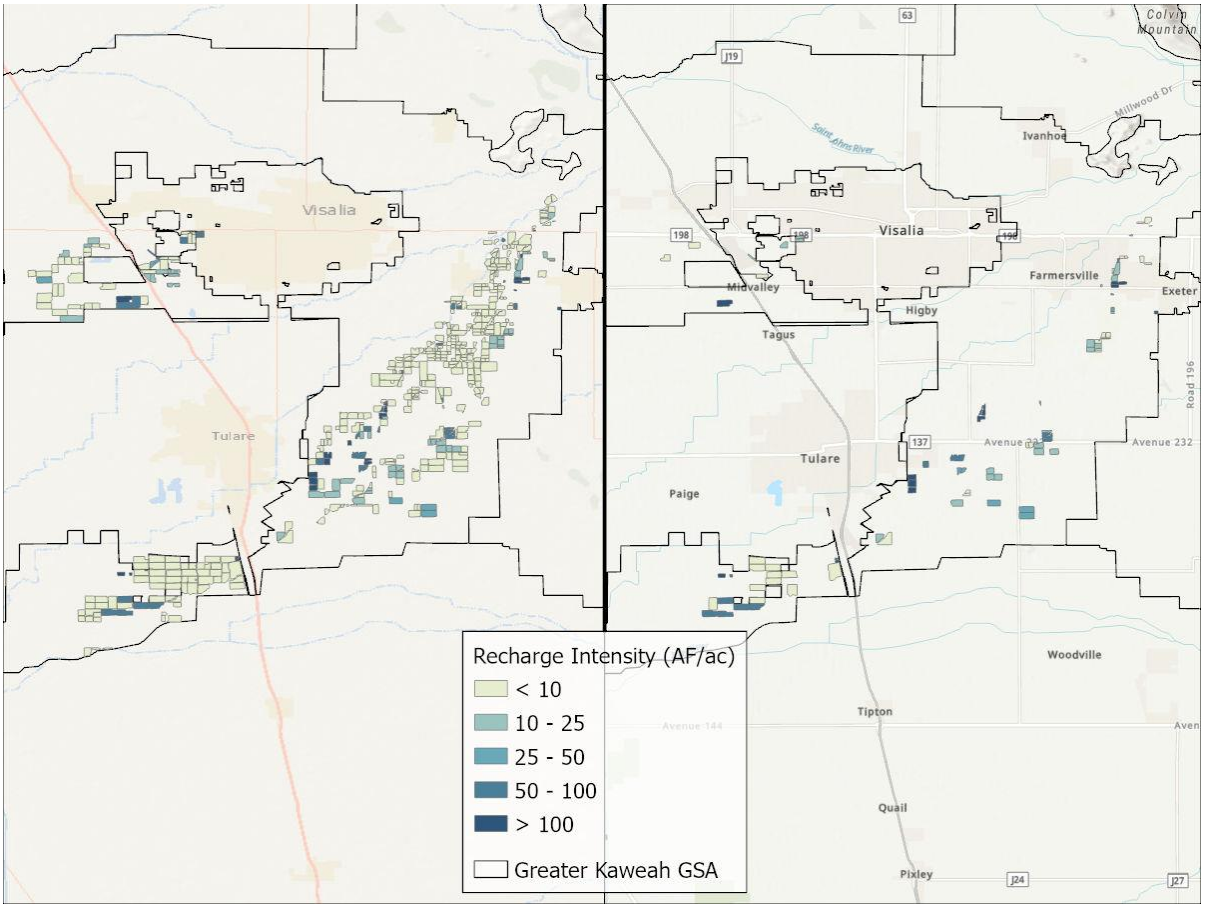


Figure 6. Comparison of annual recharge potential for all fields in the Consolidated Water District (left) and fields that can receive water based on canal capacity constraints (right).

Monthly Recharge Potential

In December, January, and February, recharge is conveyance limited, meaning that even with all four canals running 24 hours a day, it is not possible to deliver enough water to flood all the available fields to their capacity. The slight variation in monthly recharge potential (Figure 7) is due to the number of days in each month, with the exception of March. In March, one of the ditch companies (Elk Bayou) becomes land use limited, meaning that there is not enough land on which to spread all the water that the canals can deliver without damaging crops. This is primarily due to the cotton fields, which dominate Elk Bayou. Cotton fields are suitable for recharge after harvest (mid-late October), but the soils need time to dry before planting at the beginning of April, which means that on most soil types, cotton fields cannot be used for recharge in March. Nevertheless, 42% of potential recharge in the area can occur on cotton farms with suitable soils. The growers on these lands would be crucial partners in building a regional recharge program (Figure 8). Walnut and pistachio orchards may allow for additional recharge in March, but could not tolerate all of the potentially delivered water (Figure 9). This means Elk Bayou could increase its recharge potential without investing in new infrastructure simply by incentivizing some farmers to switch to growing

crops that are compatible with on-farm recharge in March (e.g., switching from cotton to sweet potatoes).

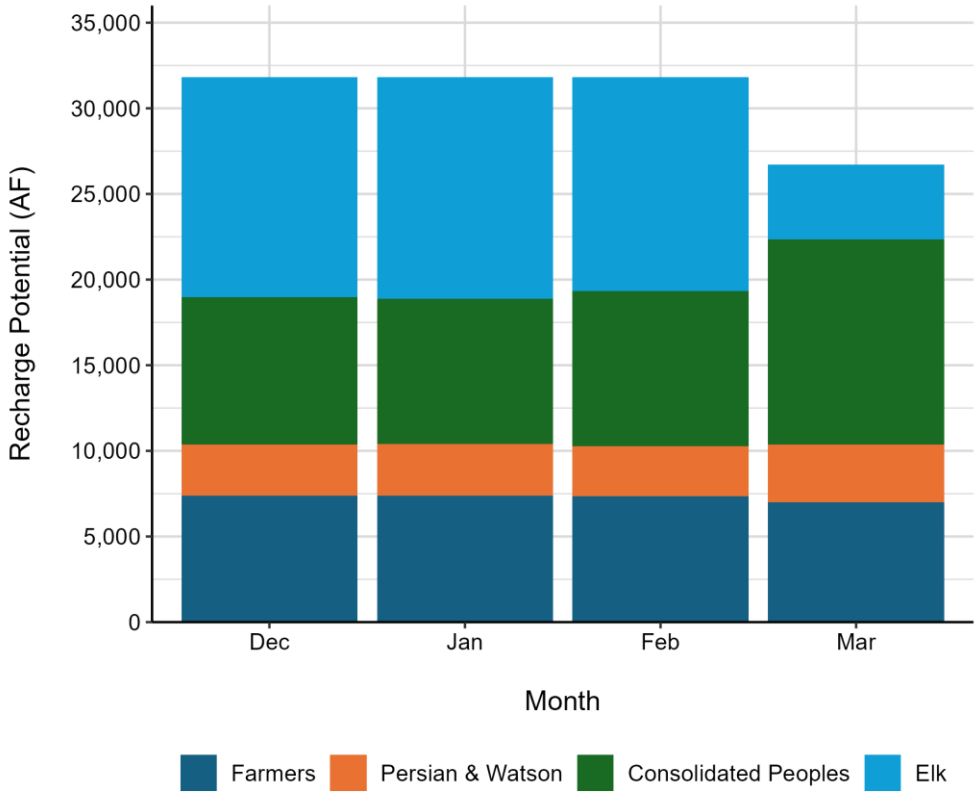


Figure 7. Monthly recharge potential by service area, in AF.

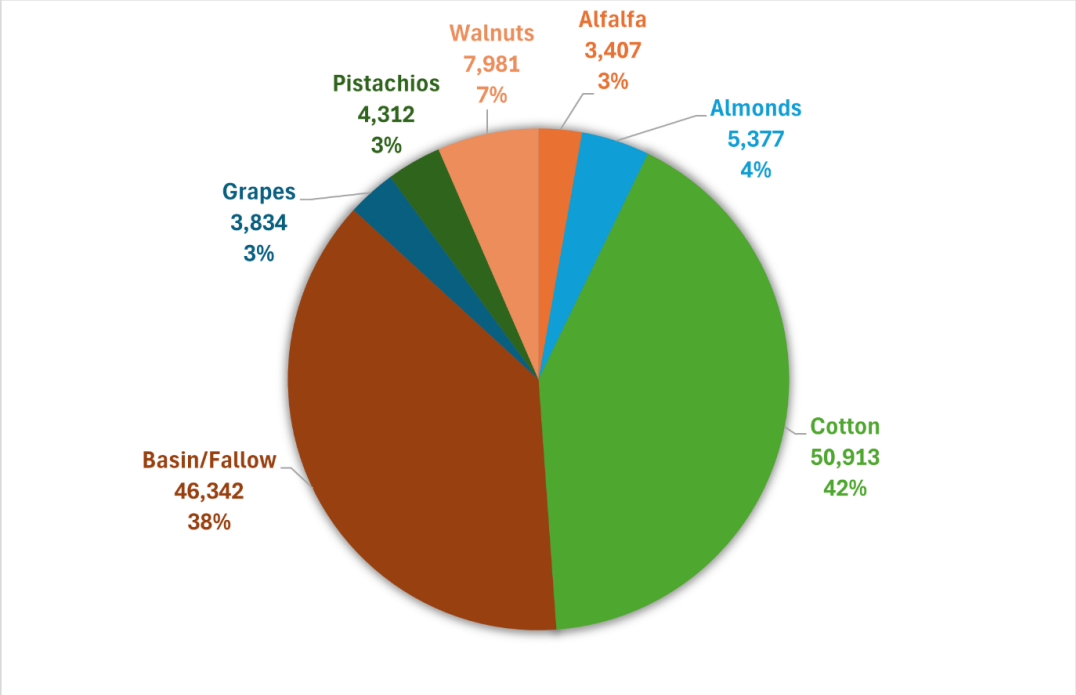


Figure 8. Annual on-farm recharge potential by land use, in AF.

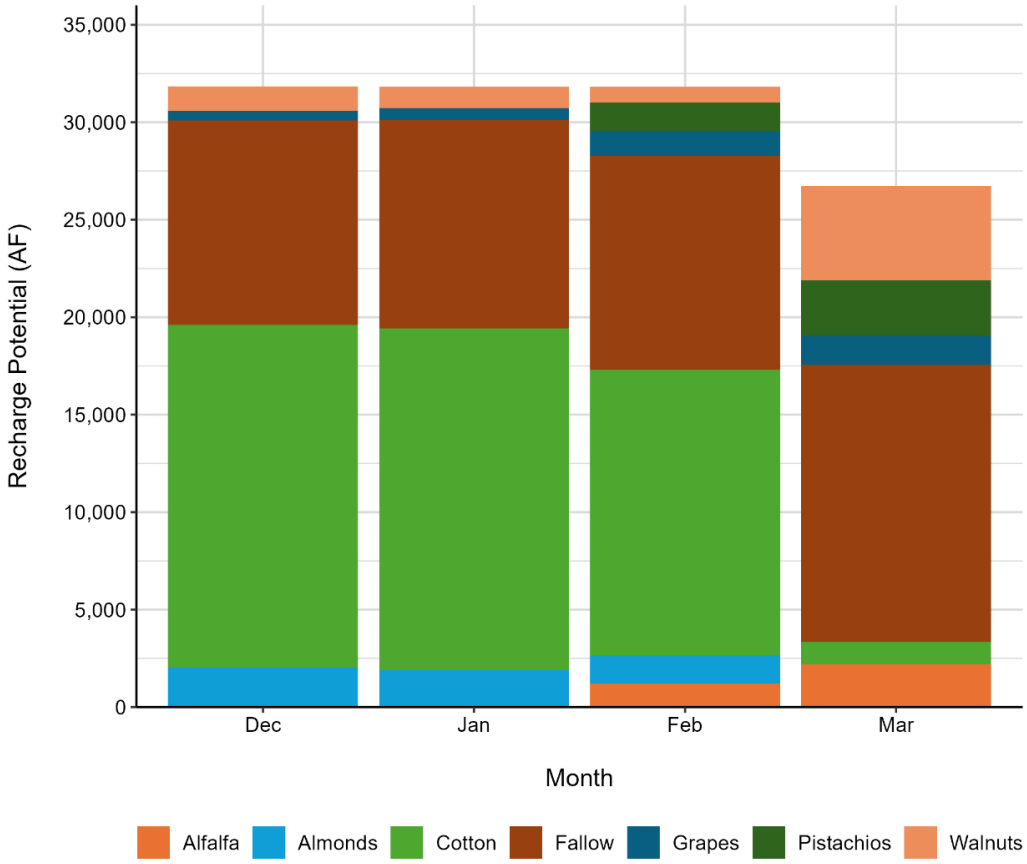


Figure 9. Monthly on-farm recharge potential by land use, in AF.

Scaling and Expanding RapidGRAT

This effort involved piloting the first RapidGRAT, which required determining its features and functionality, building the Python code, and working with the Consolidated Water District to identify and gather the necessary data. Now that RapidGRAT has been developed for the Consolidated Water District, the code can be applied to data for other regions interested in the tool. Depending on how a region has collected and compiled its data, acquiring the data for the tool may be the main challenge. Sufficient time should be allocated for data collection and wrangling in the tool development timeline.

The Consolidated Water District and other regions that implement RapidGRAT in the future can use the tool not only to inform potential recharge program opportunities, but to inform other decisions as well. Examples include:

- Quantifying recharge and water rights needs for agencies or districts without water rights for recharge, which could be used in tandem with a water rights application for recharge.
- Using monthly or daily recharge potential to compare with daily flood hydrographs to estimate flood reduction benefits from reductions of source flows.

- Comparing the recharge potential of all fields with the amount of recharge that can be done based on canal capacity constraints. Water managers can consider strategically expanding headgate and canal constrictions to achieve more recharge. This sort of documentation can support applications for state (e.g. Proposition 4 grants) and federal funding in support of groundwater sustainability.

In addition to expanding RapidGRAT geographically, there may be features that water managers are interested in that can be built in with some more effort. For example, specific groundwater benefits can be achieved by targeting recharge in specific areas instead of focusing on optimizing recharge to the fields with the highest recharge potential. For example, the location of the Corcoran Clay can be used to target recharge on fields connected to the confined layer that are more likely to reduce subsidence (Figure 10). Alternatively, areas near towns like Hypericum could be targeted to benefit community drinking water supply. In this case, a groundwater model would help in assessing exact locations to recharge to achieve the benefit. A complementary tool to RapidGRAT could be a static "viewer" that would allow water district and GSA managers to view and sort specific fields based on co-benefits derived (e.g., drinking water supply protection or subsidence prevention) or recharge rate. Output products could be maps or lists of specific fields that could be tied to APNs to target outreach to growers.

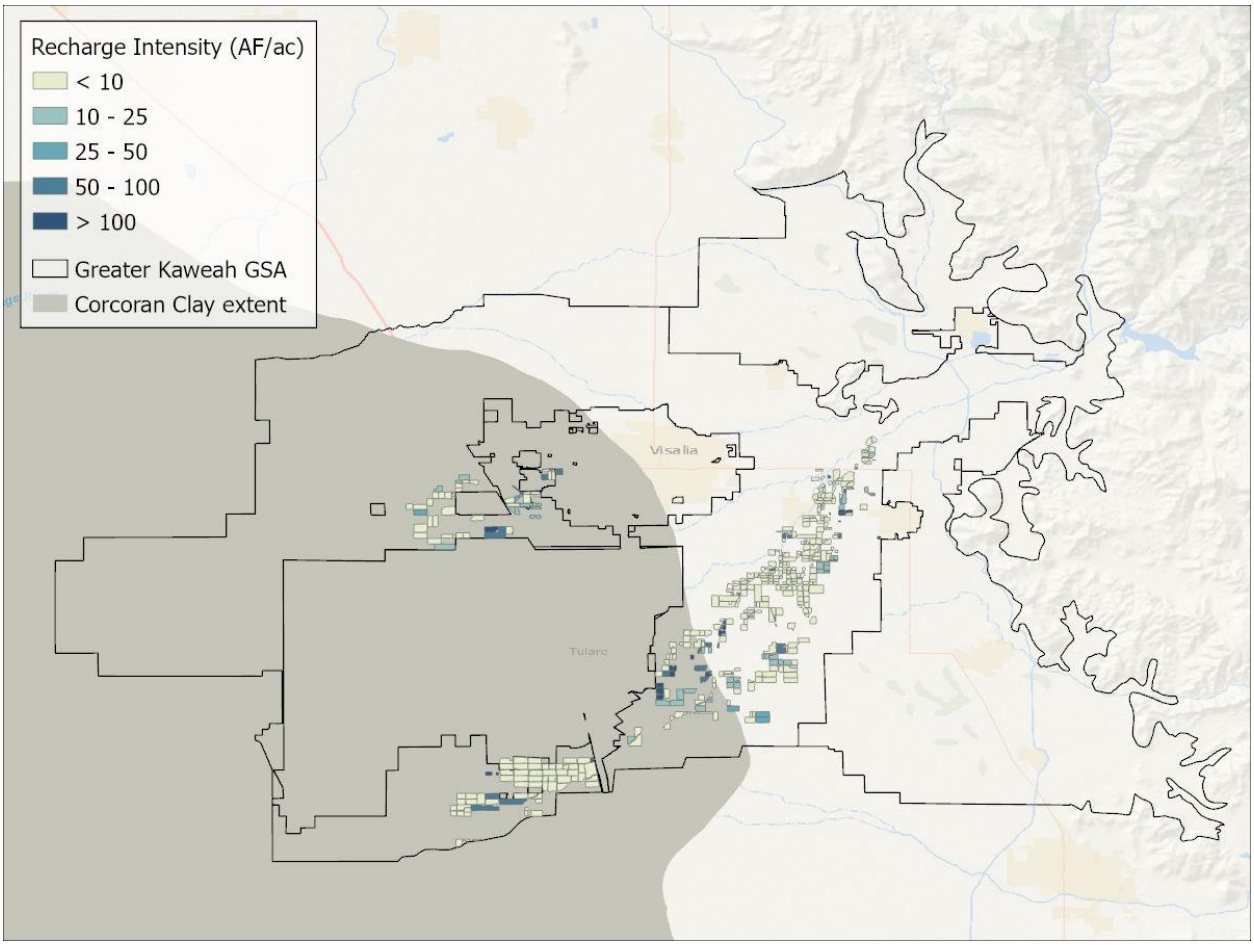


Figure 10. Recharge potential of all fields in the Consolidated Water District over the Corcoran Clay extent.

Conclusion

The scale of recharge benefits shown to be possible in the Consolidated Water District using its existing conveyance capacity will require acceptance and buy-in by farmers on at least 245 fields and winter operation of canals by all four ditch companies. Note that RapidGRAT does not consider operational constraints, such as the ability to deliver water during high flow events to specific recharge sites. There may also exist labor or financial constraints that may make the results of this assessment more difficult to achieve. Nonetheless, RapidGRAT can inform the upper bound of the volumes of water that could be recharged in a region. The potential benefits of this scale of recharge can include reducing overdraft and associated groundwater pumping costs, reducing flood flows on rivers, and avoiding or reducing pumping restrictions under SGMA. Farmers in the district with the best crop and soil combinations for recharge may need to be incentivized to maximize their recharge through financial payments or groundwater pumping credits. Groundwater sustainability under SGMA requires coordination across GSAs within the entire subbasin and these study results can be used to show the potential contribution of the Consolidated Water District to

the overall health of the groundwater basin as a management action in the Groundwater Sustainability Plan.

Appendix A: Monthly On-Farm Recharge Limits

Recharge potential, in AF, by crop type, month, and soil suitability

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Alfalfa													
Excellent	18.57	20.00	17.26	10.47	10.84	5.59	4.54	5.23	7.50	0	0	0	**100.0**
Good	6.20	5.60	4.87	4.11	2.23	3.18	2.82	3.00	3.00	0	0	0	**35.0**
Moderately Good	1.91	1.73	1.69	1.76	1.33	1.33	1.50	1.50	1.50	0	0	0.12	**14.4**
Moderately Poor	1.08	1.02	0.73	0.76	1.11	1.26	1.00	1.16	1.56	0	0	0	**9.7**
Poor	1.11	0.96	0.71	0.75	0.98	0.96	1.05	1.09	1.22	0	0	0	**8.8**
Very Poor	1.05	0.91	0.64	0.71	0.85	0.76	0.92	0.98	1.07	0	0	0.07	**8.0**
Almonds													
Excellent	22.14	17.14	0	4.00	0	3.58	0.42	0	0	17.69	21.54	21.48	**108.0**
Good	4.07	3.23	0	2.00	0	0	0	0	0	5.63	6.25	5.83	**27.0**
Moderately Good	1.61	1.05	0	0	0	0	0	0	0	1.54	1.17	1.68	**7.1**
Moderately Poor	1.17	0.91	0	0	0	0	0	0	0	0.84	1.09	1.36	**5.4**
Poor	0.94	0.65	0	0	0	0	0	0	0	1.09	1.11	1.31	**5.1**
Very Poor	0.84	0.45	0	0	0	0	0	0	0	1.08	0.96	1.10	**4.4**
Cotton													
Excellent	46.50	42.00	34.50	0	0	0	0	0	0	15.00	45.00	46.50	**229.5**
Good	46.50	42.00	16.50	0	0	0	0	0	0	15.00	45.00	46.50	**211.5**
Moderately Good	33.33	26.88	0	0	0	0	0	0	0	10.78	32.33	33.41	**136.7**
Moderately Poor	16.78	13.54	0	0	0	0	0	0	0	5.43	16.29	16.84	**68.9**
Poor	14.85	11.98	0	0	0	0	0	0	0	4.83	14.49	14.97	**61.1**
Very Poor	12.33	9.94	0	0	0	0	0	0	0	4.02	12.07	12.47	**50.8**
Fallow													
Excellent	46.50	42.00	46.50	45.00	46.50	45.00	46.50	46.50	45.00	46.50	45.00	46.50	**547.5**

Good	46.50	42.00	46.50	45.00	46.50	45.00	46.50	46.50	45.00	46.50	45.00	46.50	**547.5**
Moderately Good	32.68	29.52	32.68	31.83	32.89	31.83	33.17	33.17	32.10	32.83	31.78	32.83	**387.3**
Moderately Poor	15.94	14.40	15.94	15.63	16.15	15.63	16.43	16.43	15.90	16.09	15.58	16.09	**190.2**
Poor	14.08	12.72	14.08	13.83	14.29	13.83	14.57	14.57	14.10	14.23	13.78	14.23	**168.3**
Very Poor	11.60	10.48	11.60	11.43	11.81	11.43	12.09	12.09	11.70	11.75	11.38	11.75	**139.1**
Grapes													
Excellent	20.00	20.00	17.91	19.23	0	0	0	0	0	12.14	21.43	19.29	**130.0**
Good	4.98	6.09	5.71	4.29	0	0	0	0	0	3.04	5.36	5.54	**35.0**
Moderately Good	1.38	1.82	2.02	0.07	0	0	0	0	0	0.88	1.56	1.61	**9.3**
Moderately Poor	1.04	1.28	1.04	0.23	0	0	0	0	0	0	1.14	1.35	**6.2**
Poor	1.26	0.84	1.29	0.04	0	0	0	0	0	0.61	1.21	1.31	**6.6**
Very Poor	1.10	0.74	1.11	0	0	0	0	0	0	0.59	1.05	1.13	**5.7**
Pasture													
Excellent	22.47	22.14	0	0	0	0	0	0	0	0	11.54	23.85	**80.0**
Good	5.96	3.59	0	0	0	0	0	0	0	0	3.41	7.05	**20.0**
Moderately Good	2.10	1.73	0	0	0	0	0	0	0	0	1.05	2.18	**7.1**
Moderately Poor	1.32	1.68	0.27	0	0	0	0	0	0	0	0.44	1.65	**5.36**
Poor	1.28	1.59	0.12	0	0	0	0	0	0	0	0.54	1.57	**5.10**
Very Poor	1.11	1.43	0	0	0	0	0	0	0	0	0.55	1.34	**4.43**
Pistachios													
Excellent	23.35	21.54	10.74	12.00	6.80	0	0	0	0	20.00	15.00	18.57	**128.00**
Good	5.19	5.83	4.69	3.16	2.32	0	0	0	0	5.00	4.07	5.74	**36.00**
Moderately Good	1.85	1.76	1.32	1.11	0.52	0	0	0	0	0	0.96	1.43	**8.95**
Moderately Poor	1.46	1.25	1.28	1.67	1.50	0.17	0	0	0	0	1.13	1.13	**9.59**
Poor	1.05	1.14	0.85	1.10	1.29	0.04	0	0	0	0	0.49	1.25	**7.21**
Very Poor	0.99	0.80	1.06	1.40	1.24	0	0	0	0	1.08	0.49	0.98	**8.04**
Sweet Potatoes													
Excellent	46.50	42.00	46.50	31.50	0	0	0	0	43.50	46.50	45.00	46.50	**348.00**
Good	46.50	42.00	46.50	10.50	0	0	0	0	43.50	46.50	45.00	46.50	**327.00**

Moderately Good	33.12	29.92	23.51	0	0	0	0	0	32.23	33.28	32.20	33.28	**217.54**
Moderately Poor	16.53	14.93	11.73	0	0	0	0	0	16.95	16.67	16.13	16.67	**109.61**
Poor	14.61	13.20	10.37	0	0	0	0	0	15.19	14.81	14.33	14.81	**97.32**
Very Poor	12.11	10.93	8.59	0	0	0	0	0	12.84	12.31	11.91	12.31	**81.00**
Tomatoes													
Excellent	46.50	42.00	18.00	0	0	0	0	0	16.50	46.50	45.00	46.50	**261.00**
Good	46.50	42.00	0	0	0	0	0	0	16.50	46.50	45.00	46.50	**243.00**
Moderately Good	33.48	15.12	0	0	0	0	0	0	12.97	33.28	32.20	33.28	**160.33**
Moderately Poor	16.99	7.68	0	0	0	0	0	0	7.41	16.67	16.13	16.67	**81.55**
Poor	15.04	6.79	0	0	0	0	0	0	6.73	14.81	14.33	14.81	**72.51**
Very Poor	12.51	5.65	0	0	0	0	0	0	5.82	12.31	11.91	12.31	**60.51**
Walnuts													
Excellent	20.71	15.00	19.40	18.46	0	0	0	0	0	0	23.08	23.35	**120.00**
Good	5.68	4.09	4.31	2.00	0	0	0	0	0	0.21	6.25	6.46	**29.00**
Moderately Good	1.29	1.73	2.23	2.20	0	0	0	0	0	0.11	1.63	1.88	**11.07**
Moderately Poor	1.48	0.86	1.38	0.60	0	0	0	0	0	0	0.87	1.40	**6.59**
Poor	1.20	0.99	1.25	0.33	0	0	0	0	0	0	1.06	1.38	**6.21**
Very Poor	0.95	0.94	1.11	0.22	0	0	0	0	0	0	0.99	1.20	**5.41**

Note: These volumes must be applied over the entire month in accordance with GRAT's daily Crop Compatibility Calendar. These monthly limits on their own are not intended to guide recharge operations.