Sustainable Water Management Strategy for Specialty Crop Expansion in the Sacramento Valley

Task 5 Report:

Scenario Development

JUNE 2018

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Prepared By

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1. INTRODUCTION

Through its RUCS program, SACOG has developed a suite of business tools, models, and business plan as resources for entrepreneurs, jurisdictions, developers, investors, and other stakeholders to help inform policy and investment decisions and that support and enhance the region's rural economic and environmental priorities and strategies.

The RUCS program is underpinned by a toolkit which assesses environmental and economic factors to help estimate outcomes from future strategies and plans for the use of resource lands. This offers a platform that enables users to identify inputs and outputs of the agricultural system and run scenarios that compare specialty crop production with a range of competing uses.

By integrating environmental data with the traditional economic metrics at the heart of every business, the RUCS toolkit offers a means to simultaneously evaluate financial and "ecosystem services" valuation for quantifying natural resource values. Such metrics could help determine appropriate compensation for growers that preserve and enhance these societal, economic, and environmental benefits. These tools could help stakeholders incentivize behaviors that renew and restore the natural assets that underpin our regional economy, such as recharging groundwater, improving soil health, maintaining floodplains, `sequestering carbon, or fostering habitat.

Safeguarding the Future

For farmers, enhancing ecosystem services, and groundwater recharge in particular, can have near-term impacts to many of the inputs critical to their operation and therefore the viability of their enterprise and the businesses that rely on their crops for processing and other food-related economic activities. Proactively working to sustain and fortify these foundational resources can help to strengthen resilience and long-term viability of the agricultural economy for this region. Moreover, improving water supply reliability creates a competitive edge for the region's growers over those operating in a more uncertain environment. Many higher-value crops such as nuts and other orchard crops, are accompanied by higher demand for water than many lower value crops. With typically high returns, many of these permanent crops offer compelling economic opportunity, however they come along with a low tolerance for uncertainty. Farmers growing an annual crop—plants that live for just one season and must be replanted anew each growing season-- have the option to fallow their field or switch to a different crop for a given year, as drought or other restrictive conditions may dictate. However, tree crops have a 'hardened' water demand, requiring a certain amount each year to stay alive, regardless of drought or other extenuating circumstances. Moreover, orchards and vineyards require a large up-front investment to establish a new crop, with several years of operations and management before the plants are mature enough to produce fruit, and therefore produce revenue. As a result, many growers may be averse to entering these riskier, high-value markets if they lack confidence in a continual, adequate water supply that this investment would depend on. Improving reliability of the region's water supply can not only make farmers more resilient, but also provide a dependable input that would reduce the risk of growing these higher value specialty crops, increase the opportunity to diversify into new specialty crops, and improve their ability to participate in untapped markets.

Groundwater is an indispensable resource for California's agricultural economy. On average, groundwater supplies 40 percent of water for California's farms and cities, with an even higher reliance during drought years (Chapelle 2017). In dry years when surface water is in diminished supply, farmers and municipalities lean on these resources to supply more of their water needs. Through California's recent prolonged droughts, users in hydrologic basins across the state have relied heavily on groundwater resources, depleting groundwater supplies much faster than they are able to replenish, leading to a state of overdraft. As farmers shift toward production of higher-value orchard and vineyard crops in pursuit of greater returns, these crops also come along with limited flexibility. Once an orchard is established, farmers require a certain amount of water to irrigate their crops, whether or not drought conditions constrict available water supplies. These trends necessitate greater water supply reliability.

Water supply reliability is greatly supported by balancing the use of surface water with supplies from aquifers. Groundwater recharge strategies, which rely largely on flooding fields and other open lands with available surface water so water can percolate down to aquifers, are now an important component of plans to ensure future water supply reliability. As water managers across the state explore strategies to supplement water supplies during drought years, researchers have found that groundwater recharge is far less costly than other projects that aim to increase storage or generate supply. A team of researchers at Stanford surveyed groundwater recharge projects— including those that use injection wells and other managed aquifer recharge methods— and found that costs varied widely, ranging from $90-$1,100 per acre-foot with a median project cost of $390 for surveyed projects (Rohde 2014). By comparison, expanding reservoir capacity costs roughly $1,700-$2,700 per acre-foot, and desalination of seawater costs between $1,900 to over $3,000 per acre-foot (Rohde 2014). On-farm recharge has proven to be even more cost effective than the median cost per acre-foot of groundwater recharge projects because these agricultural flooding strategies eliminate many of the infrastructure and maintenance costs associated with injection wells or similar types of managed recharge programs. While more research is needed to assess scalability of these results, an on-farm recharge project in the San Joaquin Valley cost approximately $36 per acre-foot (Bachand 2016). The project team evaluated all the existing literature and worked with agronomic experts to identify specialty crops that are most tolerant and otherwise best suited for on-farm flooding regimens, as described in Task 3. Many of these crops are the very high-value crops that require a relatively high demand and a reliable supply of irrigated water. As such, these growers may be the most interested in supporting strategies that restore and sustain regional water supply. Others may be enticed by the ability to diversify into new specialty crops, while some may be incentivized if water markets are such that they receive payments for fallowing or loss of crop value if they flood their fields for the benefit of the larger region. Combined with the hydrogeologic and soil suitability that this project has explored, lands growing crops suitable to recharge can be strategically flooded at times when water is abundant, so that farmers can restore the groundwater supply and bank these resources, saving up for a not-so-rainy day. By shoring up the groundwater supply that so many regional growers rely on, farmers can bolster their resilience and strengthen the future of the region's agricultural economy as a whole.

2. METHODOLOGY

2.1. STUDY AREA

The surface and sub-surface suitability index developed in Task 3 identified areas across the region where the landscape reflects suitable soil and hydrogeologic conditions to allow for efficient and effective recharge if managed flooding recharge practices were to be implemented on these lands. The project also drew on available research to identify which specialty crops are suitable for— and tolerant to— flooding.

The base case scenario evaluates how much recharge could be achieved if farmers currently growing this selection of crops on recharge-suited land were to implement a realistic flooding regimen. The scenarios imagine cropping changes within these areas that have ‘good’ and ‘fair’ recharge suitability but are not currently growing recharge-tolerant crops, to illustrate the potential benefits that could be achieved on these lands through different management and cultivation strategies. The study area also excluded fields that were not inside an irrigation district boundary and those identified as non-irrigated[1], as described in Task 2, in order to limit the scenario analysis to fields that are likely to have the necessary water conveyance infrastructure to deliver water to their fields for recharge flooding.

2.2. RECHARGE CROPS

As described in Appendix A., infiltration rates and approximate recharge volume estimates were developed for a handful of good and fair recharge suitability crops, including almonds, prunes, grapes, walnuts, pistachios, as well as annual crops that are fallowed in winter months when the recharge flooding would occur. These crop-specific ratings include the most dominant recharge-suitable specialty crops grown in the SACOG region. For the handful of other recharge-suitable crops in the region, representative recharge estimates were derived by averaging the figures for each of the crops that share their same crop-suitability rating.

Idle or fallow land is not a specialty crop; however, this analysis included idle acreage with the existing suitable specialty crop acreage, reflecting the ability for currently idle land to be flooded without risk to the land cover. These acres offer an opportunity for landowners to flood their fields

[1] The Irrigation Type index classifies all idle land as ‘non-irrigated.’ This analysis only included idle fields within irrigation district boundaries for scenario recharge flooding.

for recharge benefits while idle, and potential to establish specialty crops that could benefit from the resulting increase in groundwater supply reliability.

2.3. RECHARGE FLOODING REGIMEN

The project team modeled recharge estimates based on winter-season flooding practices, with applications from November through March. Winter flooding strategies offer a handful of benefits by targeting annual crops between planting seasons and orchard crops during their dormant season prior to bud-break. Winter-timed flooding also tends to limit the additional water demand to months when precipitation is higher in California, agricultural consumption is low, and rates of evapotranspiration- and corresponding water loss- are much lower than in summer months. Three quarters of the state's precipitation occurs between November and March, and roughly half occurs from December and February (State of California 2015). Flooding fields at times when precipitation is high, particularly in upland areas that feed the region's rivers, may also provide opportunity to capture and divert peak flows that may had otherwise flowed out to the oceans, and the potential to reduce the added stress on the region's levee infrastructure that occurs when water levels are high.

For annual specialty crops grown in the region— such as tomatoes, melons, squash, and beans— the winter flooding would occur outside of their growing season. These crops essentially become idle or fallowed land for a few months of the year, providing opportunities for recharge flooding before growers must begin prepping their fields for the next season's production cycle.

Recharge flooding strategies for orchard and vineyard crops, however, must account for the ongoing viability of the crop. Recharge application volumes are adjusted to limit risk of root zone damage, which could lead to reduced yields or harm to the orchard stock. Dispersing a smaller amount of water consistently over a longer period would allow growers to maximize recharge, without drowning the crop in too much water at once. Limiting this risk to a farmer's agricultural assets may increase the likelihood that a grower would adopt these recharge flooding practices, which could lead to more land area participating in recharge activities on the whole. For these permanent crops, the scenario modeling assumes flooding over a 150-day period, from November through March. For annual and idle lands, without these crop-restrictions, the scenarios assume 45 days of water application over the designated time period to account for water availability, land preparation, and other cultural practices. Given that recharge in these areas is not limited by potential for harm to the crop cover during the fallowed winter season, the infiltration rates for annual crops in these good and fair recharge-suitability areas were calculated based on the soil texture and corresponding infiltration rates for each parcel's soil type.

While there are many external factors that limit researchers' ability to precisely estimate real-world effects of recharge in a discrete area, this project utilized the best-available data and expertise to estimate the approximate recharge volume that stakeholders could anticipate as a result from on-farm recharge flooding under a range of crop-specific conditions, as specified in Table 1. A detailed description of the methods and resources used to estimate recharge volumes is provide in Appendix A.

Table 1. Average Recharge Volume and Mounding Estimates for Specialty Crops

Crop Type	Average Infiltration Rate[1] (ft/day)	Average Annual Volume Recharged in 20-acre Field[2] (acre-feet/year)	Estimated Groundwater Elevation Rise from Recharge (Mounding)					
			Poor Hydrogeologic Suitability[3]		Fair Hydrogeologic Suitability[4]		Good Hydrogeologic Suitability[5]	
			Max Height (ft)	Height at 2,000 ft (ft)	Max Height (ft)	Height at 2,000 ft (ft)	Max Height (ft)	Height at 2,000 ft (ft)
Almonds	0.20	613	34.1	10.0	3.8	1.7	1.5	0.7
Prunes	0.34	1,016	55.6	20.0	6.4	2.8	2.5	1.2
Walnuts	0.47	1,420	74.3	23.3	8.7	3.9	3.5	1.6
Pistachios	0.22	650	37.3	11.0	4.1	1.8	1.6	0.8
Wine Grapes	0.41	1,222	65.8	20.4	7.7	3.4	3.0	1.4
Low End of Range for Annual Crops[6]	0.4	1,200	64.4	19.9	7.5	3.3	3.0	1.4
High End of Range for Annual Crops[6]	1.6	4,800	204.7	75.5	28.3	12.9	11.4	5.5

[1] Average infiltration rates for permanent crops based on successful rates from recently completed studies evaluating tolerances for specific crops. Rates for annual crops based on values for bare soil types associated with annual crops in the study area. All infiltration rates are assumed to be in excess of crop water demand during the recharge period and to exclude precipitation.

[2] Average annual volume recharged assumed to be equivalent to the infiltration rate multiplied by the number of days and area. The average recharge period is assumed to be 150 days from November 1st through March 31st. Representative field size of 20-acres based on average existing or potential specialty crop fields in the study area.

[3] Poor Hydrogeologic Suitability based on the combined hydrogeologic recharge suitability index. For Hantush (1967) mounding analyses the following aquifer parameters were used: Kh=10 ft/day, Sy=0.05, Saturated Thickness=180 ft.

[4] Fair Hydrogeologic Suitability based on the combined hydrogeologic recharge suitability index. For Hantush (1967) mounding analyses the following aquifer parameters were used: Kh=150 ft/day, Sy=0.15, Saturated Thickness=150 ft.

[5] Good Hydrogeologic Suitability based on the combined hydrogeologic recharge suitability index. For Hantush (1967) mounding analyses the following aquifer parameters were used: Kh=600 ft/day, Sy=0.3, Saturated Thickness=100 ft.

[6] Annual Specialty Crops are tomato, cucurbit, and dry beans.

3. SCENARIOS

SCENARIO | RECHARGE FLOODING WITH BASE CASE CROPS

Parameters:

The base case establishes the potential quantity of additional groundwater volume that could be achieved with current cropping and land use patterns, through implementation of an on-farm recharge program throughout the region. The scenario results were limited to only fields with good or fair soil and hydrogeologic suitability, as determined in Task 3. The scenario estimated recharge potential of a winter recharge-flooding program on the 14 identified specialty crops with 'good' or 'fair' recharge suitability, including almonds, pistachios, prunes, walnuts, grapes, melons, squash, and cucumbers, apples, pears, pomegranates, bush berries, tomatoes, and kiwis.[2]

SCENARIO | EXPANDING FLOOD-TOLERANT SPECIALTY CROPS ON IDLE LANDS

Parameters:

This scenario estimates the potential groundwater recharge benefits for the region, if the idle cropland in areas with 'good' or 'fair' surface and subsurface suitability were to grow flooding-tolerant specialty crops. The scenario analysis identified areas rated 'good' or 'fair' in the combined soil and hydrogeologic suitability index, which are identified as cropland, but are currently not growing any crops in the 2014 base case. The scenario converts these areas to recharge-tolerant specialty crops, including almonds, pistachios, prunes, walnuts, wine grapes, melons, squash, and cucumbers, apples, pears, pomegranates, and bush berries. These crops are expanded in acreage based on their relative proportion in the base case and are allocated based on cropping production factors (including soil texture, county production trends, etc.).

SCENARIO | RECHARGE FLOODING WITH SPECIALTY CROP EXPANSION

Parameters:

This scenario estimates the potential groundwater recharge benefits for the region, if all cropland in areas with 'good' or 'fair' surface and subsurface suitability were converted to grow flooding-

[2] Production cost and return data from UCCE is unavailable for kiwis, so the SACOG Cost and Return tool is not able to model any Cost and Return data for these crops. As such, the existing 180 acres of kiwis within the study area was included in potential recharge volume calculations, but kiwi acreage was not expanded in any of the scenarios.

tolerant specialty crops. The scenario analysis identified areas rated 'good' or 'fair' in the combined soil and hydrogeologic suitability index, that are currently growing non-specialty crops. The scenario converts these areas to the list of recharge-tolerant specialty crops, including almonds, pistachios, prunes, walnuts, grapes, melons, squash, and cucumbers, apples, pears, pomegranates, bush berries, and tomatoes. These crops are expanded in acreage based on their relative proportion in the entire base case geography (including areas with poor recharge potential or outside the hydrogeologic basin study area) and are allocated based on cropping production factors (including soil texture, county production trends, etc.).

SCENARIO | FALLOWING FOR RECHARGE UNDER SGMA PLANS

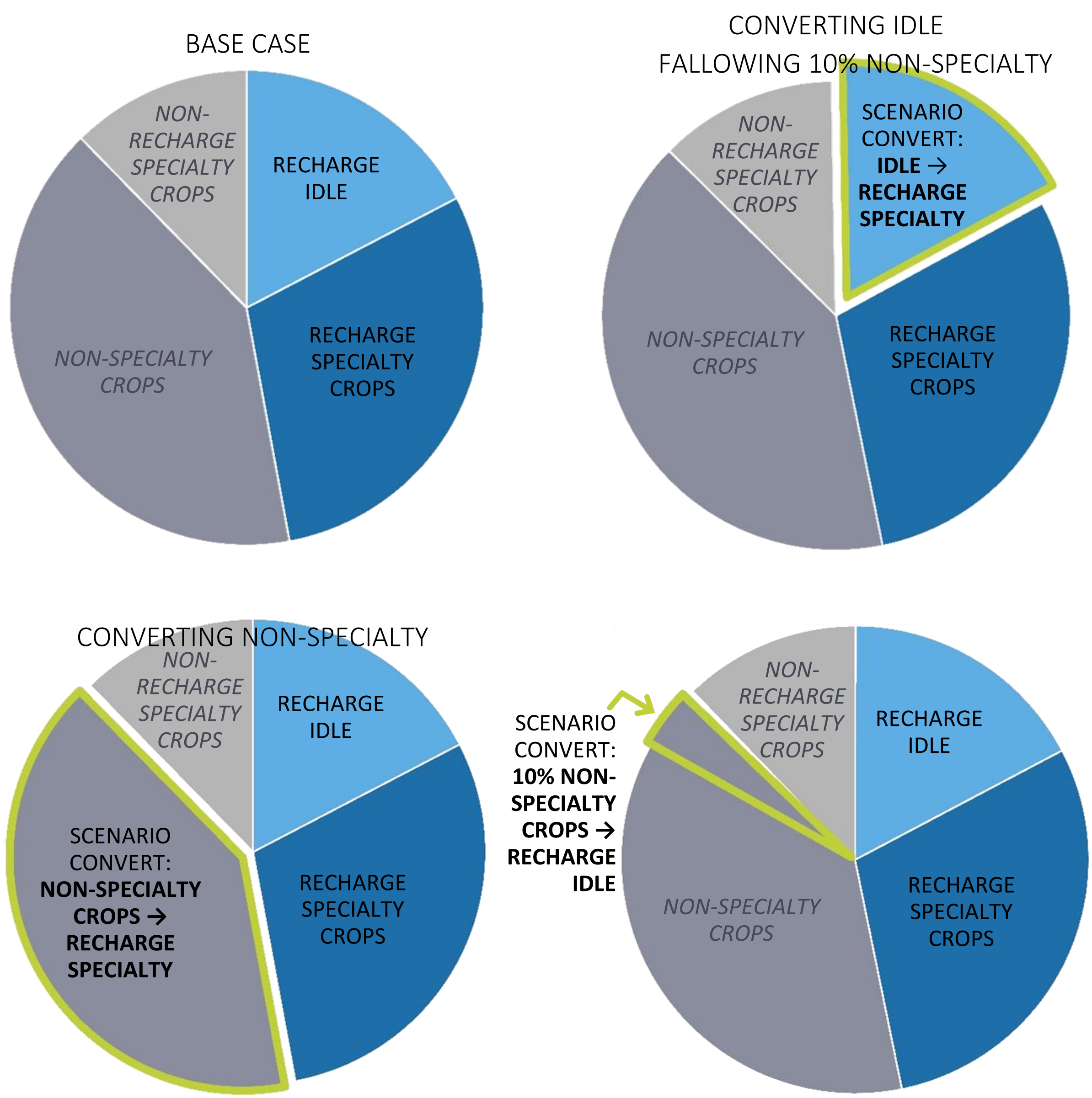
Background:

Stakeholders across the region are currently working on Groundwater Sustainability Plans, which will provide the region's framework for sustainable groundwater management, in keeping with California's 2014 Sustainable Groundwater Management Act (or SGMA). This project's outreach and feedback sessions engaged many of the stakeholders that are involved in developing these plans, through their involvement with Groundwater Sustainability Agencies (or GSAs) formed under SGMA. GSAs for each identified basin comprise various local stakeholders, responsible for creating and implementing a plan to bring groundwater supply and use in balance, in keeping with SGMA regulations. To limit curtailments on groundwater use, GSAs are exploring a variety of strategies for groundwater recharge projects. This scenario was developed in response to these stakeholder outreach discussions.

Parameters:

This scenario fallowed 10 percent of the non-specialty crops grown on land with 'good' or 'fair' recharge potential (converting these lands to 'idle'), totaling 13,900 acres. In this scenario, these fallowed lands would be managed as dedicated winter recharge sites to provide additional recharge capacity for the hydrogeologic basin, which would improve water supply reliability for specialty crops. Stakeholders indicated that when water supplies are restricted, non-specialty crops are often the first to be fallowed, owing to their annual planting cycle and typically lower returns. The scenario targeted these dedicated fallow recharge areas with the best conditions to facilitate recharge, selecting for parcels within irrigation district boundaries with 'good' recharge potential, soil types with the highest infiltration rates, gravity-fed irrigation.

Figure 1. Scenario Acreage by Crop and Recharge Category



4. RESULTS

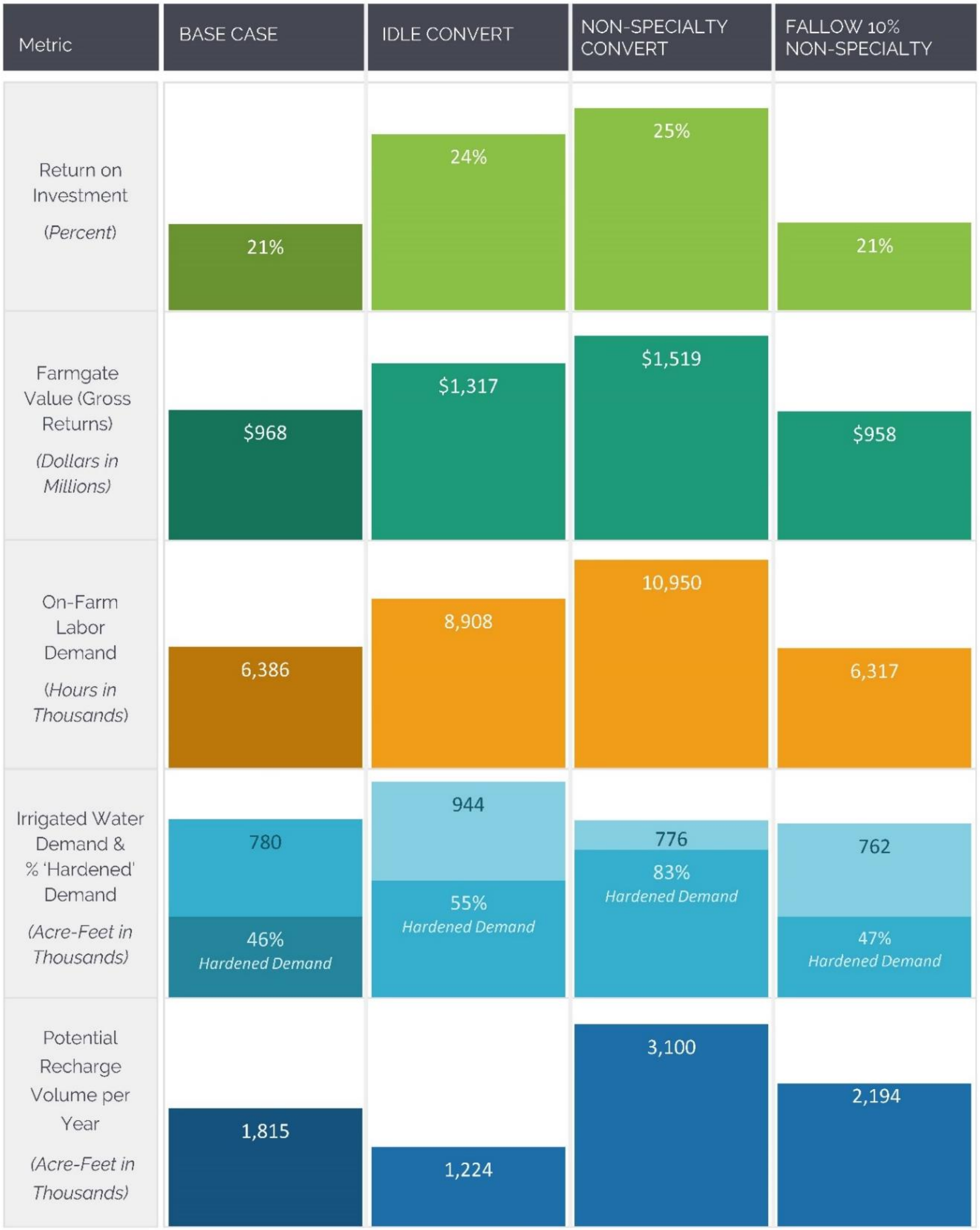
The scenario analysis revealed that annual specialty crops provide a more robust opportunity for recharge, as compared with permanent specialty crops, such as orchards or vineyards. Table 2 shows the relative percentage of scenario recharge acreage and recharge volume that occurs on annual specialty crop land versus perennial specialty crop land. While annual recharge specialty crops make up less than half of recharge acreage (including idle land acreage), these areas are responsible for nearly three quarters of total potential recharge volume. Annual specialty crop growers are able to flood their crops during winter months, when crops are not in the ground, so these growers are better able to apply recharge water liberally, without concern for harming their trees or vine stock. For instance, recharge capacity fell 34 percent when idle lands were replaced by other recharge specialty crops, owing to the increase in orchard lands replacing the low-restriction idle lands. The expansion of orchard croplands means that these areas are relatively restricted in their recharge capacity, when compared with annual vegetable crops or idle lands, where land managers are not restricted by risk of crop damage if flooding occurs outside of the growing period.

Table 2. Base Case Recharge Metrics by Percent Annual vs. Perennial Crop Recharge Sites

BASE CASE METRIC	Recharge Acres	Total Recharge Volume (acre-feet/yr)
Total (Value)	167,080	**1,815,080**
% of Total from ANNUALS	40%	74%
% of Total from PERENNIALS	60%	26%

However, this scenario provides significant economic advantages when idle lands are replaced with recharge-suitable specialty crops. Putting these lands into cultivation increases farm-gate value by 36 percent and grows return on investment by 15 percent. And though it may be at a slower rate of infiltration overall, there is still opportunity for recharge to occur on these crops. The analysis found that if there were sufficient buy-in from growers and available water to flood every identified field in the study area with good crop, soil, and hydrogeologic suitability, estimated recharge volumes would exceed crop production water use in each scenario examined, with the exception of the scenario replacing idle land with an orchard-heavy mix of recharge specialty crops. This dynamic is due to the large decrease in annual recharge areas, which offer the best recharge potential.

Figure 2. Comparison of Scenario Results Key Metrics



Conversion of non-specialty crops to the selection of recharge specialty crops increases gross returns by 57 percent and grower return on investment rises by 20 percent, as compared with the base case. However, the increase in value generated also comes along with a 71 percent increase in labor hours, totaling an additional 4.5 million hours of labor across the study area. This need for additional labor may pose a challenge, as growers in the region have already reported challenges in finding adequate labor supply to harvest current crop production. Beyond increased yields, this scenario also demonstrates greatly increased capacity for specialty crop recharge. These increased lands provide nearly 140,000 additional acres of recharge potential, which could yield up to an additional 1.2 million acre-feet of water each season of recharge flooding at full adoption of these practices and available water supply. While replacing non-specialty crops with an orchard-heavy blend of specialty recharge crops increases returns across the study area, the additional acreage of permanent crops means that 83 percent of irrigated water demand is 'hardened,' decreasing flexibility for farmers in the study area overall to fallow crops when water supplies are limited or water costs spike. Once established, orchard crops require a certain amount of water each year to survive. This increase in hardened water demand makes water supply reliability much more critical for the study area as a whole, and recharge efforts that much more critical when surplus water is available.

Fallowing 10 percent of non-specialty crop lands in the scenario represents the most modest change to the base case of any of the scenarios examined. While the sweeping changes to the landscape in the other two scenarios is a powerful tool to illustrate trends and trade-offs that accompany different types of changes, this scenario presents a more modest change to the landscape, and the implementation of a recharge strategy that stakeholders on the ground are considering as a measure to improve groundwater supply and reliability for existing and future specialty crop production. Fallowing 13,900 acres of non-specialty land brings modest decreases in overall returns, compared with the base case. Returns and net revenues decrease about one percent from current conditions. Despite a small economic impact on the scenario's overall cost and return profile, this scenario helps to decrease water demand for the scenario overall, reducing irrigated water demand by nearly 18,500 acre-feet per year. In addition to reducing demand, fallowing non-specialty production provides a large increase in potential recharge volume. The additional idle lands provide an additional 21 percent volume over the base case, amounting to an opportunity to recharge nearly 380,000 acre-feet of additional groundwater each season.

Table 3. Comparison of Scenario Estimated Recharge Benefits

Metric	Recharge Area Type	BASE CASE	IDLE CONVERT	NON-SPECIALTY CONVERT	FALLOW 10% NON-SPECIALTY
Recharge Acres	*Perennial*	100,750	137,150	201,310	100,710
Applied Recharge Water (acre-feet/yr)	*Perennial*	509,510	697,870	1,030,090	509,260
Recharge Volume (acre-feet/yr)	*Perennial*	469,540	643,590	950,600	469,310
Recharge Acres	*Annual (incl. Idle)*	66,330	29,920	104,880	80,250
Applied Recharge Water (acre-feet/yr)	*Annual*	1,368,970	591,340	2,186,190	1,753,440
Recharge Volume (acre-feet/yr)	*Annual*	1,345,540	580,770	2,149,130	1,725,090
Recharge Acres	**Total**	167,080	167,080	306,190	180,960
Applied Recharge Water (acre-feet/yr)	**Total**	1,878,480	1,289,210	3,216,280	2,262,700
Recharge Volume (acre-feet/yr)	**Total**	1,815,080	1,224,360	3,099,730	2,194,400

Table 4. Comparison of Scenario Water Input, Consumption, and Net Recharge Volume

Metric	BASE CASE	IDLE CONVERT	NON-SPECIALTY CONVERT	FALLOW 10% NON-SPECIALTY
Irrigation Demand (acre-feet)	780,070	780,070	944,360	776,180
Annual Total Acre-Feet Applied (for Recharge & Irrigation)	2,658,550	2,233,570	3,992,450	3, 024,500
Net Groundwater Recharge Volume (acre-feet/yr)	1,815,080	1,224,360	3,099,730	2,194,400
Net Increase of Groundwater (as a percent over loss & plant consumption)	**215%**	**121%**	**347%**	**264%**

Table 5. Scenario Recharge Results as an Increase or Decrease Over Base Case Findings

Metric	IDLE-CONVERT VS. BASE		NON-SPECIALTY CONVERT VS. BASE		SGMA FALLOWING VS. BASE	
Total Recharge Acres (including idle)	--	--	+139,110	+83%	+13,880	+8%
Total Applied Recharge Water (acre-feet/yr)	+589,270	-33%	+1,337,800	+71%	+384,220	+20%
Total Recharge Volume (acre-feet/yr)	-590,720	-34%	+1,284,650	+71%	+379,320	+21%
Irrigation Demand (acre-feet)	+164,290	+21%	-3,890	-0.5%	-18,270	-2%
Annual Total AcFt Applied (for Recharge & Irrigation)	-424,980	-16%	+1,333,900	+50%	+365,950	+14%

Table 6. Comparison of Scenario Cost and Return Metrics

Metric	BASE CASE	IDLE CONVERT	NON-SPECIALTY CONVERT	FALLOW 10% NON-SPECIALTY
Acres *(Total ag. production, not including Idle)*	285,900	346,100	285,900	272,000
Total Costs	$800,316,900	$1,060,375,900	$1,214,396,400	$791,153,700
Total Gross Returns	$968,391,900	$1,316,771,100	$1,519,173,700	$957,727,500
Total Net Revenue	$168,075,000	$256,395,200	$304,777,300	$166,573,800
Average ROI	21%	24%	25%	21%
Irrigation H2O (acre feet)	780,100	944,400	776,200	761,800
Hardened Water Demand (acre feet)	355,000	514,900	648,000	355,000
% Total Water Demand Hardened	46%	55%	83%	47%
Irrigation Water Cost	$50,356,100	$64,176,100	$64,941,100	$49,039,800
Labor Cost	$95,159,400	$130,807,900	$158,810,700	$94,102,500
Labor (hrs)	6,386,200	8,908,100	10,949,500	6,317,200
Yield (tons)	1,906,400	2,124,400	2,976,100	1,867,000
Truck Trips (to transport harvest yield)	87,200	100,200	135,100	85,400

Table 7. Scenario Cost and Return Results as an Increase or Decrease Over Base Case Metrics

Metric	IDLE-CONVERT VS. BASE		NON-SPECIALTY CONVERT VS. BASE		SGMA FALLOWING VS. BASE	
Total Costs	+$260,059,000	+32%	+$414,079,500	+52%	-$9,163,200	-1%
Total Gross Returns	+$348,379,200	+36%	+$550,781,800	+57%	-$10,664,400	-1%
Total Net Revenue	+$88,320,200	+53%	+$136,702,300	+81%	-$1,501,200	-1%
Average ROI	+3%	+15%	+4%	+20%	--	--
Irrigation H2O (acre feet)	+164,300	+21%	-3,900	-0.5%	-18,300	-2.3%
Hardened Water Demand	+159,900	+45%	+293,000	+83%	--	--
Irrigation H2O Cost	+$13,820,000	+27%	+$14,585,000	+29%	-$1,316,300	-3%
Labor Cost	+$35,648,500	+37%	+$63,651,300	+67%	-$1,056,900	-1%
Labor (hrs)	+2,521,900	+39%	+4,563,300	+71%	-69,000	-1%
Yield (tons)	+218,000	+11%	+1,069,700	+56%	-39,400	-2%
Truck Trips (transport harvest yield)	+13,000	+15%	+47,900	+55%	-1,800	-2%

4.1. FLOODING IN RESPONSE TO HIGH PRECIPITATION EVENTS

These scenarios operate under an assumption that recharge water is available and accessible by growers to flood their fields, in keeping with the parameters outlined. The study focused on the which lands and crops in the region offer the best opportunity for recharge but did not account for the complex system of laws governing water rights in California. These scenarios explore recharge programs with regimented water application across a season, to illustrate the potential that could be attained with the necessary water supply and grower buy-in.

However, throughout the stakeholder outreach sessions, growers and water managers in the region cited potential to conduct recharge flooding during high-precipitation events. The majority of California's rainfall occurs in the period from November to March, and the total precipitation volume usually comes from a handful of small storms (State of California 2015). While some of this precipitation occurs in the mountains as snow, which can slowly melt and disperse through the watershed throughout the year, a large amount occurs as rainfall and ends up being flushed out to the ocean by rivers and streams. Additionally, these episodes of precipitation tend to occur in a somewhat constrained time period, so later season rainfall may occur when existing reservoir storage is already at full capacity. This pattern presents an opportunity for water managers to divert a portion of the water in these peak flow events, to capture for later use through groundwater recharge. Table 8 shows the expected recharge volumes that could be achieved through a short-term flooding program, in response to a high-precipitation even in the region or its source headwaters. The table below estimates the potential groundwater recharge that could be achieved over one week of recharge flooding.

Table 8. Scenario Recharge Potential Over One Week of Flooding

Metric	BASE CASE	IDLE CONVERT	NON-SPECIALTY CONVERT	FALLOW 10% NON-SPEC.
Acres	167,080	167,070	306,190	180,960
Recharge Volume *(acre-feet over 7 days of flooding)*	326,847	250,350	569,171	385,791

Through Executive Order B-36-15 issued on November 13th, 2015, Governor Brown directed state water regulatory boards to accelerate approvals for projects that "use high water flows to recharge local groundwater while minimizing flood risks" during that year's upcoming rainy season, removing some barriers to make it easier for local water managers to divert these peak flows that would otherwise flow out to sea and capture them for recharge (CA EO B-36-15).

Current policies governing water access and rights could make diversions of water for recharge flooding for an entire winter season prohibitively complex or expensive, particularly at a regional scale. However, the type of recharge program laid out in this Executive Order is limited to "projects that enhance the ability of a local or state agency to capture high precipitation events [in the next] winter or spring for local storage or recharge, consistent with water rights priorities and protections for wildlife." By diverting excess water during these peak events, recharge efforts are limited to water that would have otherwise flowed out to sea. As the Executive Order also notes, diversions of peak flows can also decrease flood risk for communities adjacent to waterways, in addition to providing relief to levees by reducing the strain that high flow levels place on these infrastructural assets.

This strategy offers a low-barrier recharge opportunity that can leverage existing land area and conveyance infrastructure to capture water when it becomes available.

While rainfall is occurring within the region, fields may already be saturated to capacity, and farmers of permanent crops may be reticent of damage that could be caused if they were to put additional water on their orchard or vine crops. However, much of the state's precipitation occurs in higher-elevation areas, such as the Sierra Nevada mountain range in the Eastern part of the region. As that water makes its way through the hydrologic system, excess flows can be diverted from streams and rivers to flood farms in lower-lying areas in the 6-county region.

5. ECOSYSTEM SERVICES AND HABITAT CO-BENEFITS

In addition to the myriad ecosystem service benefits recharge flooding provides, including restoring aquifers and improving water supply reliability for the region, flooding in particular areas of the SACOG region can also provide wildlife habitat benefits. As of 2009, California had lost over 90 percent of the state's historical wetland area (California Water Boards 2009). A diverse array of species in the region rely on a shrinking supply of wetlands and other winter-flooded areas. As urbanization and other pressures continue to diminish the availability of these habitats, flooded agricultural fields can provide surrogate habitat for these vulnerable species within the region.

Targeting on-farm flooding to areas that can offer habitat co-benefits can expand support for these recharge efforts. Growing a diverse coalition of support also has the potential to access new avenues of funding to support agricultural flooding programs.

Table 9 shows the acreage of habitat which overlaps with flooding-suitable agricultural fields and that could be enhanced by winter flooding programs and recharge efforts. Acreage is displayed by county and broken out by recharge suitability class. The areas identified here are limited to just the boundaries of identified habitat area, from the California Natural Diversity Database. For some habitat benefits— such as winter flooding to provide surrogate pacific flyway habitat that mimics historic wetlands— growers near the existing habitat areas could extend the habitat range of species that may utilize their winter-flood fields as a place to rest, eat, breed, etc. As such, these estimated could be considered conservative, limited only to the existing areas in use by endangered wildlife habitat. Table 10 links this habitat potential to the four scenarios examined in prior sections, to evaluate the amount of flooded area that would provide habitat enhancement benefits at full adoption of scenario flooding practices.

Table 9. Acres of Priority Wildlife Habitat Areas with Good or Fair Recharge Potential for Flooding[1]

	Acreage by Recharge Suitability		
COUNTY	FAIR	GOOD	TOTAL
Placer	487	206	**693**
Sacramento	8,649	2,775	**11,424**
Sutter	4,220	1,644	**5,863**
Yolo	6,212	1,346	**7,558**
Yuba	3,777	1,365	**5,142**
SUM	23,345	7,336	**30,680**

[1] SACOG analysis of CNDDB Habitat Data

Table 10. Scenario Comparison of Priority Wildlife Habitat Areas with Recharge Potential Flooded[1]

	Flooded Acreage			
Scenario Land Use	BASE CASE	IDLE CONVERT	NON-SPECIALTY CONVERT	FALLOW 10% NON-SPEC.
Recharge Crop	16,633	28,051	16,633	17,332
Non-Recharge Crops	14,065	2,647	14,065	11,950
Percent of Recharge-Suitable Habitat Acreage Flooded	54%	91%	54%	56%

[1] SACOG analysis of CNDDB Habitat Data

These priority wildlife habitat areas were identified based on SACOG analysis of the California Natural Diversity Database (or CNDDB), classifying threatened, at-risk, or endangered species that are likely to benefit from flooding or improved riparian health. As such, these areas primarily focus on areas that serve only the most vulnerable species in the region. Recharge flooding in potential good and fair recharge areas are likely to provide habitat benefits to a broad range of other species, beyond those vulnerable species identified in the CNDDB. On a basic level, groundwater recharge can help riparian habitat by relieving some of the demand for surface water resources when water is scarce, particularly in smaller ecosystems that may not have careful regulatory monitoring of outflows. In addition to these areas of observed species occurrence, this analysis also identified riparian corridors as an indicator of potential habitat areas that would benefit from recharge.

Riparian corridors provide wildlife habitat to a diverse range of plants and animals, allowing species to flourish that may not otherwise be suited to such an arid environment as California's. The flora that characterize these riparian corridors tend to rely a shallow depth to groundwater (Orr 2004). Overdraft in adjacent basins can threaten these species by drawing down groundwater levels below reach of the plant species that underpin these riparian ecosystems (Orr 2004). These environments also provide an important flood control buffer. Riparian habitat further downstream in the Delta would be a likely beneficiary from groundwater replenishment in the SACOG region, as overdraft in higher elevation areas can intercept flows of underground water that would have moved laterally through the subsurface to lower elevation riparian habitat areas (Orr 2004).

6. CONCLUSION

Groundwater is a critical resource that underpins the SACOG region's agricultural economy. As local stakeholders across the region and the state explore strategies to expand groundwater recharge efforts, agricultural recharge through on-farm flooding has great potential to be an effective tool for restoring aquifers and bringing use on balance with replenishment. The SACOG region has nearly 350,000 acres of agricultural land in suitable recharge areas; nearly 170,000 acres of this land could be flooded for recharge with the specialty crop currently produced there.

Unlike high-cost infrastructure projects like dam construction or expansion, groundwater recharge takes advantage of the vast water storage capacity that already exists underground. Farmlands are also likely to already have the water conveyance infrastructure necessary to divert recharge water, which non-agricultural open space lands may lack. As California's population continues to grow and open lands are developed, multi-benefit working lands management becomes increasingly important to maximize beneficial outcomes and help growers resist development pressures. Agricultural flooding during the winter allows growers to divert peak flows when water is more abundant, relieving stress on levee infrastructure and achieving habitat co-benefits for pacific flyway waterfowl and other wildlife species.

The scenario results highlight the potential for growers in the region to engage with Groundwater Sustainability Planning efforts and leverage their land to help ensure the resilience of these resources that are so critical to their businesses. Annual specialty crop lands grown on suitable soils provide the greatest recharge potential of the identified specialty crops, however— with the exception of tomatoes— these crops do not currently represent a significant acreage in the region. While crop constraints limit the recharge capacity of orchard and vineyard crops, compared with annual specialty crops, these croplands are still able to generate recharge. Several of these crops represent a large percent of the region's current crop acreage; walnuts, almonds, and wine grapes alone make up one quarter of the acreage in good and fair recharge areas. If even a portion of farmers these crops engaged in recharge flooding across a large area, the region could see significant recharge benefit, even in spite of the lower of recharge per acre. The permanent water demand of established orchard and vineyard crops means that these growers are likely to have the greatest interest in restoring aquifers and increasing water supply reliability, which may increase the prospect of on-farm recharge participation.

With full grower participation and adequate water supply, the region's growers could restore twice as much water as their crops would need for irrigation. The region's booming agricultural economy is driven by specialty crop production, which offers high returns to growers and generates significant value for the local economy. This study highlights the opportunity for these specialty crop growers to leverage the potential of their land in a new and important way. By helping to restore aquifers and improve reliability of groundwater supplies, growers can help to safeguard the resilience of this critical resource and the agricultural economy that it underpins.

This study provides data and tools to evaluate scenarios and educate stakeholders about current and future agriculture and its impact on the region, and the trade-offs between different agricultural futures. This work provides guidance on building strategies for agriculture and other land uses, and brings impactful new metrics to SACOG's analytical toolkit, enhancing a robust foundation for future analyses.

These analyses echo findings from previous work— such as SACOG's Sacramento Regional Agricultural Infrastructure project, also known as the 'Yuba Case Study'— demonstrating the profitability of specialty crops for growers in the region and how an expanding local market, as well as export markets nationally and abroad, offer a promising future for this local industry, but that sufficient water and labor supply is critical. Labor supply issues remain a barrier for expanding specialty crops in this region, particularly those that require hand-picking and other intensive tasks. However, this study provides a blueprint for the vast potential in this region for growers and water managers to break down silos and work together in efforts to restore groundwater levels and improve the sustainability of this critical agricultural input for the economy going forward into the future.

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APPENDIX A. Average Recharge Volume and Groundwater Mounding Estimates

The effects of groundwater recharge can be described in terms of increased groundwater volume and decreased depth to groundwater. The volumetric component is straightforward; every unit of water that is successfully recharged to groundwater results in a directly proportional increase in total groundwater volume. Changes in the depth to groundwater resulting from recharge in specific discrete locations are harder to estimate than are recharge volumes. This is because the movement of water recharged in discrete locations is a function of application and subsurface parameters. Estimates of average recharge volumes and mounding effects associated with specialty crops in the study area are presented below.

Average Recharge Volume Estimates

As indicated above, estimating the volume of water recharged as a result of spreading at the ground surface is relatively straightforward, with some basic assumptions. These assumptions include the following:

- The rate at which water infiltrates or the volume infiltrated is known.
- That rate or volume is in excess of evaporation and/or transpiration during the recharge period.
- No infiltrated water is lost to soil moisture during the recharge period.
- Newly recharged water does not cause discharge promptly from the groundwater system.

With these assumptions, the calculation of the volume of water recharged is simply a function of the rate at which water infiltrated, the area over which infiltration occurred, and the duration of the recharge period. Recharge rates were developed for each of the specialty crops in the study area based on recently completed studies for permanent crops for bare soil for annual crops, as discussed below.

Average Groundwater Mounding Effect Estimates

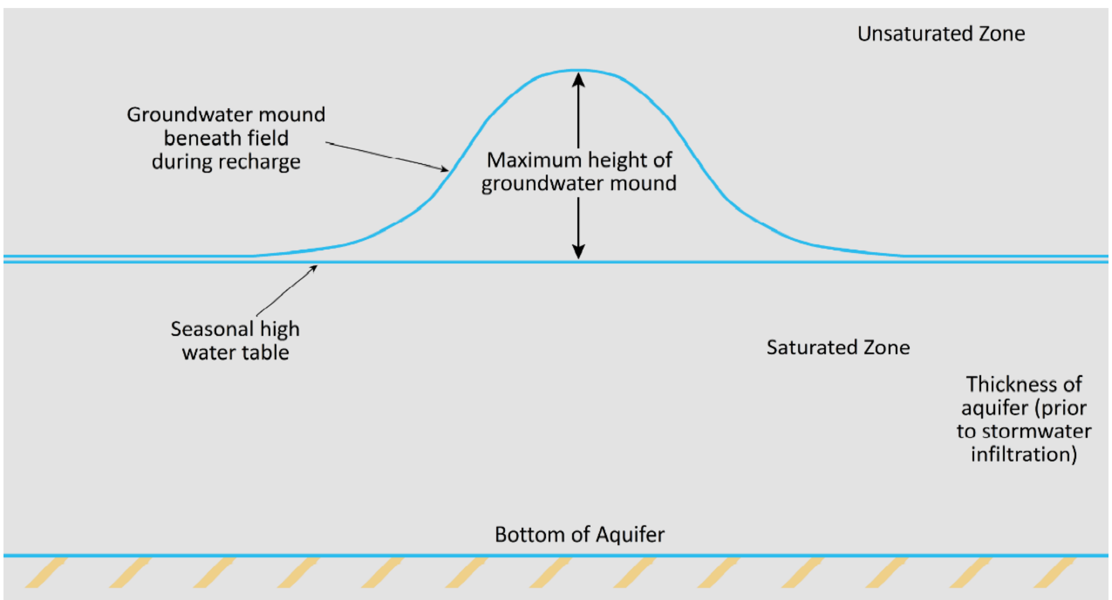
Changes in the depth to groundwater resulting from recharge in specific discrete locations are more difficult to estimate than are recharge volumes. This is because the movement of water recharged in discrete locations is a function of application and subsurface parameters. These include:

- The extent of the area over which recharge is applied,
- The rate at which recharge water is applied,
- The rate at which recharge water infiltrates to groundwater,

- The storage coefficient of the aquifer (the volume of water that can be stored and released per unit volume of aquifer material),
- Background groundwater gradients, and
- Other local recharge and discharge.

It is not possible to accurately estimate real-world effects of discrete area recharge on groundwater elevations without a thorough representation of these parameters. However, simplified analytical methods are available for assessing generalized groundwater elevation changes. Application of the Hantush equation (1967) is an industry standard approach for estimating the height of a groundwater recharge mound as a function of time and distance from the recharge area, as illustrated below in Figure 1-1:.

Figure 1-1: Generalized Groundwater Mounding from Recharge



A series of solutions to the Hantush equation were calculated to examine scenarios representing the range of possible combinations of infiltration rates for specialty crops and varying hydrogeologic conditions present within the evaluation area. In each case, the recharge area was simulated as a representative 20-acre with a square shape. This configuration was identified as representing the average existing or potential new specialty crop field in the study area (Ormiston 2018).

As with the average annual recharge volume estimates discussed above, the mounding estimates were completed for each specialty crop type based on average infiltration rates. The mounding estimates were calculated for three subsurface conditions representing hydrogeologic index conditions of Poor, Fair, and Good. Calculations were completed for each of the recharge rates for the various specialty crops for each subsurface condition. It was assumed that these recharge rates are over and above evapotranspiration demands. All Hantush simulations were completed assuming a recharge period of 150 days representing an average recharge period beginning November 1st and ending March 31st. The results shown in Table 1 present the maximum height and the height at a radial distance of 2,000 ft for the groundwater mounds resulting from each hydrogeologic condition and application rate.

The estimated maximum mound height under the recharge area varied from 0.02 to over 200 ft. In general, the more permeable the subsurface the lower the mound. This relationship suggests that the mound from recharge in lower permeability areas will rise higher as the flow of water away from the field is slower. While groundwater mound heights are greater in less permeable material, the effects will take a longer time to propagate horizontally.

This mounding analysis provides a range of estimated groundwater mounding as a result of recharge on a representative 20-acre field at infiltration rates based on recently completed studies and soil properties. The size and shape of groundwater mounds resulting from recharge will be affected by actual recharge/infiltration rates, recharge area size and shape, and subsurface conditions. The height and extents of groundwater mounds resulting from real-world recharge in agricultural fields would be cumulative and non-linear (i.e., the mound height of a 40-acre area would not be twice that of a 20-acre area). Additional analytical mounding estimates can be completed on a field-scale basis for individual specific locations once they have been identified. Alternatively, a simplified numerical groundwater model employing a non-linear change approach could be used to estimate the effects of recharging on multiple fields throughout the SACOG area. These studies should be based on field evaluations of infiltration rates and recharge water availability at specific sites.

Infiltration Rates Used in Mounding Estimates

Infiltration rates for permanent and annual crop land were determined using information from the following sources:

- Survey of reasonable infiltration and recharge rates by Central Valley growers
- Published estimates of infiltration rates for soils of different texture
- Soil types of study sites where agricultural recharge is being studied in field experiments in California, and their estimated infiltration rates
- Determination of soils that would likely be present at recharge sites

Survey Results

As documented in The Task 2 report, Regional Water Conveyance Infrastructure and Hydrology, in the absence of completed academic research on the quantities of recharge water that crops can tolerate, Mountjoy (2017) collected survey information from field agronomists and farmers in the San Joaquin Valley who have experience with applying recharge water. Table 1 shows the median values from this survey information of estimated recharge water in excess of crop water demand that could be applied at different periods of the year/crop cycle. These values were based on experience with recharge on well drained soils (SAGBI index value of 4 or 5) and typical climate and growing conditions within the San Joaquin Valley. These values are being continually updated each year as more field measurements are collected.

Table 1. Estimated Recharge Water Application Rates in excess of Crop Water Demand for Select Specialty Crops

Specialty Crop	Estimated Recharge Water Application in Excess of Crop Water Demand (acre-inches)[1]		
	Nov. – Mar.	Dec. – Feb.	Jan. – Dec.
Almonds	30.64	24.47	45.45
Wine Grapes	61.11	38.38	71.86
Pistachios	32.50	20.00	38.50
Walnuts	71.00	53.00	87.00

[1] Median values from survey of agronomists/farmers in San Joaquin Valley with experience applying excess water for recharge. Values are specific to growing and weather conditions in San Joaquin Valley (Mountjoy, 2017)

Published Estimates of Infiltration Rates by Soil Texture

Published infiltration rates for soils of different textures were reviewed and summarized in Tables 2 and 3.

Table 2. Infiltration Rates by Soil Texture

Soil Texture	Infiltration Rate (in/hr)	Source
Gravel and coarse sand	>0.80	Cornell University; USDA 2008
Sand	>0.80	USDA NRCS
Fine sand	0.50-0.75	Plant and Soil Sciences eLibrary
Sandy loam	0.35-0.80	Cornell University; Plant and Soil Sciences eLibrary
Loam	0.20-0.40	Cornell University; USDA NRCS
Silt loam	0.25-0.40	Plant and Soil Sciences eLibrary
Silty clay loam and clay	<0.20	Plant and Soil Sciences eLibrary
Clay	0.04-0.20	Cornell University; USDA 2008; USDA NRCS

Table 3. Infiltration rates for different type soils as measured by infiltrometer rings in third hour of a wet run (Johnson 1963).

Soil type	Infiltration rate (feet per day)
Gravelly silt loam	9.92
Clay loam	7.96
Silt loam	4.18
Sandy loam	3.86
Clay (eroded)	3.56
Sandy clay loam	2.84
Silty clay loam	1.44
Stony silt loam	1.10
Fine sandy loam	1.10
Very fine sandy loam	1.02
Loam	1.00
Sandy clay	0.10
Heavy clay	0.04
Light clay	0.00
Clayey silt loam	0.00

Soil Types in Recharge Study Sites in California

Agricultural recharge sites do not necessarily have infiltration rates that are typical of other recharge facilities, such as recharge ponds used for groundwater banking. While recharge ponds can be sited according to soil type and water availability alone, cropped land often has other factors that come into play, so a broader range of soil types must be considered. Three main agricultural recharge studies have been documented, though some of these are not yet completed.

At the Terranova Farm (Bachand et al. 2016), soils included in a recharge study on grapes, onions and tomatoes included fine sandy loams and loamy coarse sands, the former of which noted to have very low infiltration due to confining layers within the root zone. However, during the study, sustained infiltration rates of 2.5 in/day were observed, likely attributed to soil preparation such as deep ripping, and other crop establishment practices.

University of California (UC) researchers completed a recharge study on alfalfa (Dahlke et al. 2018), however, this site is considered somewhat anomalous because of its unusually coarse textured soils, mapped as gravelly loams. At this site, very high infiltration rates of 10.8 in/day were documented.

In an ongoing study with sites near Modesto and Delhi, UC researchers are studying recharge on almond orchards (Dahlke, 2017). These orchards have fine sandy loam and sandy soils, respectively. No measured infiltration rates have been documented for this study to date.

These studies indicate that soils with relatively coarse textures are typically chosen for agricultural recharge sites; however, these soils may still have relatively low infiltration rates because of other limiting factors such as finer-textured subsurface layers in the soil profile.

Potential Soil Infiltration Rates at Agricultural Recharge Sites

Average annual infiltration rates for permanent crops were estimated considering soil infiltration rates documented in the studies described above and from survey results (Mountjoy 2017). The total recharge rates for permanent crops from these survey results consider time needed for field preparation, and expert opinion on how much water application these crops can tolerate over and above water needed for evapotranspiration.

Infiltration rates for annual crops were determined considering the types of soils that would typically be found on agricultural sites used for recharge, including loams and coarse-textured soils, but excluding fine textured soils such as clays. Annual crops such as tomato, cucurbit and dry bean have potential for recharge because their annual winter fallow period would allow recharge activities that do not interfere with the growing season or other field preparation or crop establishment practices. (In the case of tomato, fall period depends on tomato processers' contract timing and varies from year to year and field to field.) Because it is assumed that winter recharge would take place when fields are fallowed, the only limiting factor to how much water could be applied is the amount of water the soil can infiltrate, since no crop is in the ground.

Individual average infiltration rates for the permanent and annual specialty crops in the study area are presented in Table 4. The five months between November 1st and March 31st were considered as the period during which in-field recharge would be feasible for both permanent and annual crops, based on grower and agricultural extension agent survey (Mountjoy 2017). The average recharge area was assumed to be a 20-acre field, representing the existing or potential new specialty crop fields in the study area (SACOG 2018).

The crop-specific infiltration rate for each crop was applied over this 20-acre area for a subset of time during the recharge period for each of the specialty crops to estimate the average annual volume recharged on a per-field basis. The results of this analysis are shown in Table 4. Recharge was not assumed to occur for all days during the recharge period because of field operations and water availability.

Table 4. Average Recharge Volume and Mounding Estimates for Specialty Crops

Crop Type	Average Infiltration Rate[1] (ft/day)	Average Annual Volume Recharged in 20-acre Field[2] (acre-feet/year)	Estimated Groundwater Elevation Rise from Recharge (Mounding)					
			Poor Hydrogeologic Suitability[3]		Fair Hydrogeologic Suitability[4]		Good Hydrogeologic Suitability[5]	
			Max Height (ft)	Height at 2,000 ft (ft)	Max Height (ft)	Height at 2,000 ft (ft)	Max Height (ft)	Height at 2,000 ft (ft)
Almonds	0.20	613	34.1	10.0	3.8	1.7	1.5	0.7
Prunes	0.34	1,016	55.6	20.0	6.4	2.8	2.5	1.2
Walnuts	0.47	1,420	74.3	23.3	8.7	3.9	3.5	1.6
Pistachios	0.22	650	37.3	11.0	4.1	1.8	1.6	0.8
Wine Grapes	0.41	1,222	65.8	20.4	7.7	3.4	3.0	1.4
Low End of Range for Annual Crops[6]	0.4	1,200	64.4	19.9	7.5	3.3	3.0	1.4
High End of Range for Annual Crops[6]	1.6	4,800	204.7	75.5	28.3	12.9	11.4	5.5

Notes:

[1]Average infiltration rates for permanent crops based on successful rates from recently completed studies evaluating tolerances for specific crops. Rates for annual crops based on values for bare soil types associated with annual crops in the study area. All infiltration rates are assumed to be in excess of crop water demand during the recharge period and to exclude precipitation.

[2]Avearge annual volume recharged assumed to be equivalent to the infiltration rate multiplied by the number of days and area. The average recharge period is assumed to be 150 days from November 1st through March 31st. Representative field size of 20-acres based on average existing or potential specialty crop fields in the study area.

[3]Poor Hydrogeologic Suitability based on the combined hydrogeologic recharge suitability index. For Hantush (1967) mounding analyses the following aquifer parameters were used: Kh=10 ft/day, Sy=0.05, Saturated Thickness=180 ft.

[4]Fair Hydrogeologic Suitability based on the combined hydrogeologic recharge suitability index. For Hantush (1967) mounding analyses the following aquifer parameters were used: Kh=150 ft/day, Sy=0.15, Saturated Thickness=150 ft.

[5]Good Hydrogeologic Suitability based on the combined hydrogeologic recharge suitability index. For Hantush (1967) mounding analyses the following aquifer parameters were used: Kh=600 ft/day, Sy=0.3, Saturated Thickness=100 ft.

[6]Annual Specialty Crops are tomato, cucurbit, and dry beans.

APPENDIX B. SACOG Agricultural Cost and Return Model- Background and Methodology

The University of California Cooperative Extension (UCCE), in partnership with the Department of Agricultural and Resource Economics at UC Davis, annually publishes Cost and Return studies which provide a summary of average costs assumed by growers to establish and produce a given crop as well as the returns from their sales. These studies are the authoritative source for the economics of agriculture production in California and provide the basis of the agricultural scenario analysis tool used to estimate inputs and returns of current cropping patterns and potential cropping scenarios in this study. Researchers estimate input costs based on "practices considered typical for the crop and area."[3]

Example: UC Cooperative Extension Cost and Return Study Data

[3] University of California Cooperative Extension, "Sample Costs to Establish an Orchard and Produce Almonds: San Joaquin Valley North, Flood Irrigation." http://coststudyfiles.ucdavis.edu/uploads/cs_public/8f/0c/8f0ce321-295f-409b-8d3e-267cb5fb163d/almondfloodvn2011.pdf

UC COOPERATIVE EXTENSION
TABLE 2. COSTS AND RETURNS PER ACRE TO PRODUCE PASTURE 40 AC
SACRAMENTO VALLEY-2015

	Quantity/ Acre	Unit	Price or Cost/Unit	Value or Cost/Acre	Your Cost
GROSS RETURNS					
Hay 40 Ac	2.5	Ton	185.00	463	
Graze 40 Ac	5	AUM	35.00	175	
TOTAL GROSS RETURNS				638	
OPERATING COSTS					
Fertilizer:				**68**	
Ammonium Sulfate	200.00	Lb	0.34	68	
Custom:				**191**	
Ground Application	1.00	Acre	10.50	11	
Hand Labor	2.20	Hour	13.60	30	
Swath/Rake/Bale/Roadside	2.50	Ton	48.00	120	
Broadcast Fertilizer	1.00	Acre	10.50	11	
Harrow	1.00	Acre	15.00	15	
Rotary Weeder	0.50	Acre	10.50	5	
Herbicide:				**7**	
Roundup UltraMax	1.00	Pint	4.31	5	
2,4-D	0.50	Pint	3.55	2	
Irrigation:				**73**	
Water Delivered	54.00	AcIn	1.36	73	
Interest on Operating Capital @ 5.75%				0	
TOTAL OPERATING COSTS/ACRE				339	
NET RETURNS ABOVE OPERATING COSTS				298	
CASH OVERHEAD COSTS					
Office Expense				20	
Liability Insurance 45Ac				16	
Land Lease 40 Ac				180	

Agriculture Economic Analysis Model

Drawing on the UC Cooperative Extension Cost and Return studies as its principal input, the Sacramento Area Council of Government's (SACOG) Rural Urban Connections Strategy (RUCS) has developed a scenario analysis modeling tool to calculate overall estimated costs and returns, including changes in cropping patterns given changes in input cost or commodity prices. The data from these studies is input into the model as published without any alteration by RUCS staff. As described below, the model does generate a custom crop type for strawberries and small farm categories given the lack of a study that could reflect average conditions in the study area. The model is updated when new Cost and Return studies are published. The tool currently contains cost and return data for 81 different crop types. These cost and return data are broken down to line item quantities and prices, allowing detailed analysis of factors such as water consumption and labor demand.

The UC Cooperative Extension releases studies for different regions across California. While the Cost and Return studies from the University of California Cooperative Extension used in this model are the authoritative source for the economics of agricultural production in the state, they estimate input costs and production based on typical growing practices for the area, which may not fully align to production geared to the local market. As such, some of the available Cost and Return studies are based on production methods and environmental conditions not found in the Delta region. In addition, the Delta's unique geography compounds this issue somewhat, as many complementary sources (such as County Crop Reports) publish data at the county level, but not in enough detail to isolate yields and returns on agriculture specifically for the Delta study area.

Therefore, in a few instances, the model includes data from a slightly older study based on Sacramento-region conditions, rather than a newer study based in an area with very different physical attributes. For a selection of crops where no study with similar environmental conditions is available, the cost and return data was adjusted to reflect growing conditions and practices in the Sacramento region. This study contextualized local conditions through both quantitative and qualitative research, as well as building out crop types serving the local market. The crop types subject to adjustment are listed on the following page.

Example of Crop Data Entry

Corn - Field

Inputs	
Price per Pound	$210.00
Quantity per Acre	6
Fuel - Gas	3.41
Fuel - Diesel	3.17
Lbs per unit	2,000
H2O (acinches)	31
Labor (hrs)	11.64
Yield (tons)	6.00
Land costs	230
Establishment cost	0

Source Data	
Year	2015
Region	Sacramento Valley and Nortl
Title	Sample Costs to Produce Fie
Source	UC Davis Coop Extension Cos
Updated	September 2015 by Lynnea C
Located	S:\RUCS\Crop Data\Cost of P

Table 2: Costs and Returns per Acre to PRODUCE

Gross Returns			Quantity /Acre	Unit	Price or Cost/Unit	Value or Cost/Acre
	Corn		6	Ton	$210.00	1,260
	TOTAL GROSS RETURNS					$1,260
Operating Costs						
	Fertilizer	10-34-0	151	Lb	0.55	83
	Fertilizer	Zinc Chelate 6%	2	Pint	0.91	2
	Fertilizer	20-0-0 Aqua Ammonium	250	Lb N	0.58	145
	Chemical	Sevin 5 Bait (Pellets)	2	lb	0.78	2
	Chemical	Oberon 2SC	3.6	floz	4.78	17
	Chemical	Roundup PowerMax	4	Pint	4.31	17
	Chemical	Clarity	0.5	Pint	14.880	7

The Crop Types adjusted in the RUCS cost and return tool include:

- Small Farm – Leafy Greens
- Small Farm – Nightshades
- Small Farm – Nuts
- Small Farm – Nuts (Organic)
- Small Farm – Root Vegetables
- Small Farm – Root Vegetables (Organic)
- Strawberries

Parameters and Use

The scenario analysis tool uses per-acre quantity and cost data for production inputs such as water, labor, chemical, fuel, and irrigation, as well as operating costs, overhead costs, and establishment costs. These data are multiplied by acreage of a given crop in a scenario and summed to create county-level scenario indicators of demand for production inputs. Yield and price data are used to determine revenue from production and, when compared to cost, provide net revenue, and return on investment.

Several "dials" were installed in the analysis tool. These dials adjust factors such as establishment costs, land costs, water costs, labor costs, and production yield. These dials allow for threshold analyses to show the variance in costs and returns when, for example, orchards are newly planted compared to fully mature. The model generates several key outputs, including dollars of gross output, return on investment (ROI), water use, and labor hours.

Figure 1-2:

Crop Cost and Return Summary

SUMMARY OF PRODUCTION COSTS PER ACRE PER YEAR		17	18 #	20	21	22	23	24
		Total Costs/Acre	Total Gross Returns	H2O (acinches)	Labor (hrs)	Yield (tons)	Land Costs	Establishment Cost
1	Alfalfa	$975	$1,200	21.00	6.19	6.00	$190	$114
2	Alfalfa - Organic	$1,281	$1,820	42.00	2.54	6.00	$288	$173
3	Alfalfa - Flood	$1,973	$1,995	42.00	14.84	7.00	380.00	230.00
4	Alfalfa - Sub-Drip Irr.	$2,270	$2,475	54.50	16.13	9.00	380.00	226.00
5	Almond	$3,677	$4,070	40.00	23.29	1.10	$349	$279
6	Almond - Organic	$4,377	$4,480	44.00	36.96	0.80	$916	$439
7	Apples - Fresh Market	$18,938	$18,180	36.00	367.59	9.00	$4,579	$971
8	Apples - Processing	$5,091	$6,050	6.00	94.45	22.00	950.00	0.00
9	Apples - Processing /Organic	$4,691	$4,875	6.00	96.29	15.00	950.00	0.00
10	Asparagus	$6,721	$5,320	30.00	32.48	2.00	$369	$347
11	Beans - Common Dried	$1,109	$1,080	28.00	5.19	1.13	$173	$0
12	Beans - Black-Eyed & Lima	$1,346	$1,250	30.00	6.37	1.25	$250	$0
13	Beans - Chinese Long	$9,657	$9,900	38.00	611.20	6.60	$300	$0
14	Blueberry	$30,241	$30,000	36.00	2138.02	5.00	$461	$1,335

Scenario Analysis Cost and Return Outputs

SCENARIO ANALYSIS		Input	Cost & Return Analysis				
		Acres	Total Costs	Total Gross Returns	Total Net Revenue	Average ROI	Operating
	Totals:	141,384	$390,734,893	$391,996,210	$1,261,317	0%	$276,35(
1	Alfalfa	32019.9	$30,412,637	$38,423,878	$8,011,241	26%	$16,375
2	Alfalfa - Organic		$0	$0	$0	--	$0
3	Alfalfa - Flood		$0	$0	$0	--	$0
4	Alfalfa - Sub-Drip Irr.		$0	$0	$0	--	$0
5	Almond		$0	$0	$0	--	$0
6	Almond - Organic		$0	$0	$0	--	$0
7	Apples - Fresh	209.3467	$3,781,470	$3,805,923	$24,453	1%	$1,971,
8	Apples - Processing	181.0131	$891,855	$1,095,129	$203,275	23%	$622,5
9	Apples - Processing /Organic		$0	$0	$0	--	$0
10	Asparagus	437.6523	$2,886,472	$2,328,310	-$558,162	-19%	$2,476,
11	Beans - Common Dried	2143.897	$2,133,162	$2,315,408	$182,246	9%	$1,612,
12	Beans - Black-Eyed & Lima		$0	$0	$0	--	$0
13	Beans - Chinese Long		$0	$0	$0		$0

Assumptions

The cost and return studies utilized for the scenario model are based on a hypothetical profile of an "average farm" for a particular crop type, as defined by UC Cooperative Extension researchers. The model constructs average expenditure and revenue profiles of farms. On an individual farm, differences in production methods, operational scale, and a variety of other factors can vary from this "average" profile. As such, this model is meant to operate only at the scenario level, not on an individual farm level.

The market price of crops fluctuates on a yearly basis. Similarly, the cost of inputs including labor and water costs can change over time, especially related to the recent drought which has limited California's water supply. Furthermore, different farms are at a variety of establishment levels, which can greatly affect economic return, particularly for crops such as orchards that require a longer maturation period before they produce returns. Changes in the cost or value of these variables can impact the precision of modeling results. However, for the sake of consistency within a crop's cost report, the tool uses the values specified in the crop's cost of production report.