Madera County

Groundwater Allocation Market Simulation

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Table of Contents

1. Introduction

In 2019, Madera County applied for and received a grant through the Bureau of Reclamation's WaterSMART Water Market Strategy Program to evaluate the potential for a water market that would allow certain irrigated parcels within the County to buy and sell groundwater pumping allocations. A water market is being considered as one possible component of the County's overall approach for sustainably managing groundwater resources pursuant to the requirements of the California Sustainable Groundwater Management Act (SGMA). The goal of the market is to potentially mitigate some of the adverse effects associated with necessary SGMA-related water use reductions by providing flexibility to manage groundwater allocations across irrigated parcels.

In theory, a market promotes the efficient use of limited groundwater supplies, and greater overall economic outcomes, compared to regulations alone. In Madera County, a market could also reduce extractions in areas where continued pumping may adversely affect domestic wells or result in other undesirable outcomes. However, the appropriateness and success of a market in helping to meet groundwater management goals depends on several factors, including local land use and cropping patterns, basin conditions, allocation policies, and stakeholder perceptions, among others. Water markets must be carefully designed and implemented to avoid unintended consequences and/or adverse effects.

The WaterSMART Water Market Strategy grant provided funding for Madera County to explore the potential viability and functionality of a groundwater market in the Madera County context; key objectives of the grant included:

- Conduct outreach and work with local stakeholders to define opportunities, identify concerns, and obtain feedback on alternative groundwater market strategies
- Assess the feasibility of a groundwater market in Madera County, including any potential environmental, economic, and social impacts and unintended consequences
- Develop a market strategy framework, outlining the market structure, rules, and strategies for reducing adverse effects
- Conduct a pilot groundwater market demonstration program

This report describes the process and outcomes of the two-year grant-funded effort, which was led by the County in partnership with consulting team members Corona Environmental Consulting (Corona), Kearns & West, and Wood Rogers. The remainder of this report is organized as follows:

- Section 2 provides background on groundwater management in Madera County and describes the potential role of a groundwater market in sustainably managing groundwater resources
- Section 3 describes the groundwater market stakeholder engagement process and key findings
- Section 4 highlights key considerations and factors that will affect the design and implementation of a groundwater market in Madera County
- Section 5 describes the methodology and results of the pilot groundwater market program
- Section 6 provides the project team's recommendations, lessons learned, and next steps for the County's consideration.

As an important note, the WaterSMART Water Market Strategy grant was written to include all Groundwater Sustainability Agencies (GSAs) within Madera County. However, as described in more detail in Section 4, groundwater allocations are a prerequisite for a functioning market. Currently, the Madera County GSA is the only GSA within the County that is using allocations as a strategy for demand management. In the future, other GSAs may participate in the market; however, they would need to establish groundwater allocations in order to have a tradeable commodity necessary for a market. In addition, the groundwater market being considered in Madera County would be limited to irrigated parcels with a groundwater allocation, as defined by the County GSA; at this time, the County is not considering the allowance of third parties (e.g., cities, environmental organizations) to buy or sell groundwater allocations.

2. Background

2.1 Groundwater Management in Madera County

SGMA has significantly changed the way California manages its groundwater resources. Through this legislation, the California Department of Water Resources (DWR) designated 127 high- and medium-priority groundwater basins throughout the state. Stakeholders in these basins were required to form Groundwater Sustainability Agencies (GSAs) and develop Groundwater Sustainability Plans (GSPs) to achieve sustainable groundwater management by 2040. GSAs in high-priority basins were required to begin implementation of their GSPs by 2020.

Madera County encompasses three subbasins within the San Joaquin Valley groundwater basin – the Madera, Chowchilla, and a portion of the Delta-Mendota. Each of these subbasins has been designated by DWR as "high-priority" and critically over-drafted under SGMA. Madera County serves as the GSA for the portions of each subbasin that fall within undistricted areas of the Valley in the County and are not covered by another public agency (the County GSAs cover the "white areas" shown in Figure 1). As the GSA for these areas, the County is responsible for ensuring implementation of programs and management actions necessary to achieve sustainability by 2040. Sustainable yield reflects native groundwater levels that naturally exist in the subbasin from seepage and percolation; sustainability is reached when groundwater extraction equals groundwater recharge.

As shown in Figure 1, there are seven GSAs responsible for managing groundwater in the Madera Subbasin. Four of these GSAs (Madera County, City of Madera, Madera Irrigation District, and Madera Water District), representing 94% of the area in the Madera subbasin, adopted a joint GSP in December 2019 for submittal to DWR in January 2020 (Joint GSP). There are four GSAs in the Chowchilla Subbasin (Chowchilla Water District, Madera County, Triangle T Water District and Merced County); these GSAs also worked together to develop a GSP that was submitted to DWR in January 2020.

Per the Joint GSP, approximately 545,200 acre-feet (AF) of groundwater is extracted each year in the Madera subbasin, on average. The GSP for the Chowchilla subbasin reports that total groundwater extractions in the subbasin average 308,000 AF annually. In each of these subbasins, agricultural growers within the County GSAs have very little access to surface water supplies; approximately 95% of groundwater use within these areas is used for agricultural irrigation. While some percentage of the groundwater extracted from each subbasin returns to the aquifer, much of it is "consumed" through evapotranspiration or lost to surface runoff and is no longer available to the subbasin. As defined in the respective GSPs, current average consumptive use of groundwater within the County GSA boundaries exceeds sustainable yield by approximately 111,000 AF per year in the Madera subbasin and 59,700 AF

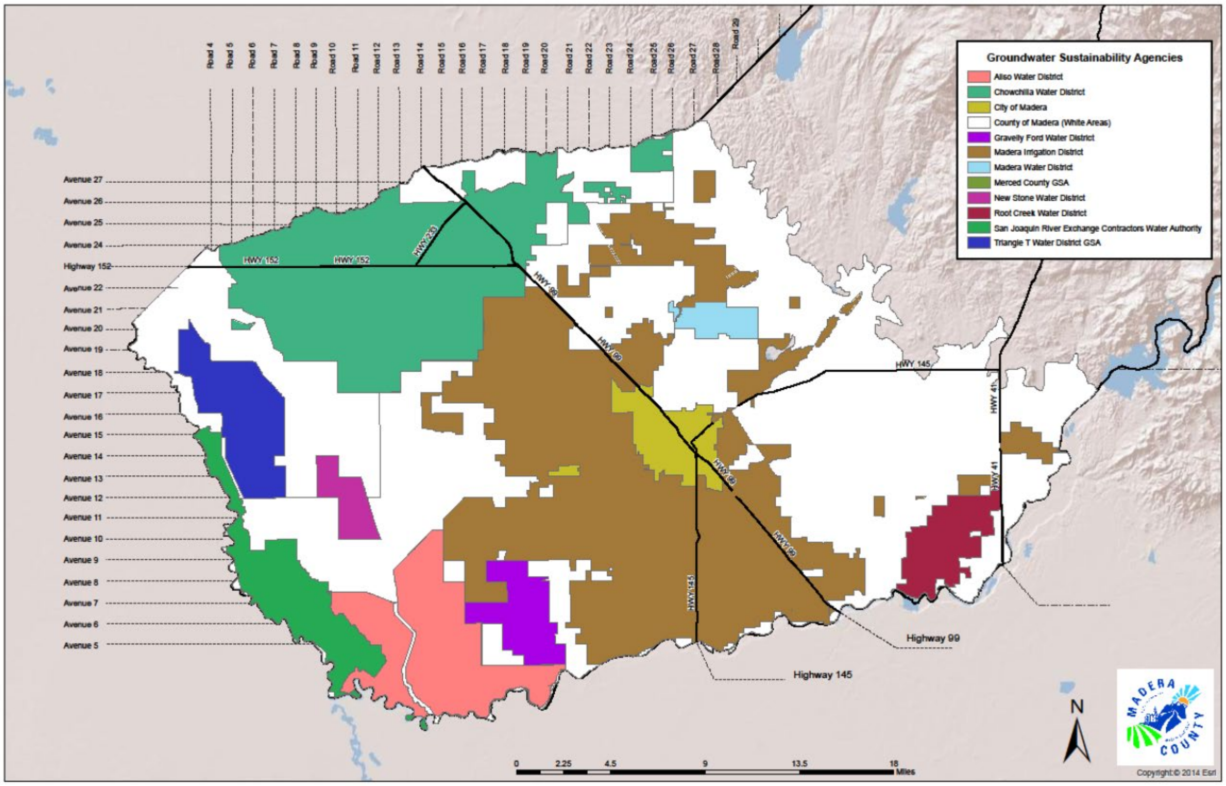


Figure 1. Map of Groundwater Sustainability Agencies in Madera County

per year in the Chowchilla, when using 2015 land use conditions as a constant.[1] This exceedance represents the amount by which the Madera Subbasin GSAs must increase recharge from new surface resources and/or reduce consumptive use demand to achieve sustainability objectives by 2040.

As described in the GSPs, the Madera County GSAs plan to implement strategies and capital projects that will result in new water supplies, including surface water purchases, new water right filings, and improved flood management to capture high flows for direct use or groundwater recharge (flood management projects will be supported by construction of various facilities to distribute captured flows). In addition to these efforts, the Madera County GSAs recognize that it will be necessary to reduce overall consumptive use of groundwater to achieve sustainable yield. Per the GSPs, Madera County GSA has committed to reducing groundwater consumption by an average of 90,000 AF per year in the Madera Subbasin and 30,000 AF per year in the Chowchilla subbasin by 2040 (note that these averages reflect the combined effect of reducing consumptive use of native groundwater and increasing the consumptive use of new surface water supplies). The County GSAs have adopted groundwater allocations for irrigated agricultural water users to help meet this goal and are considering additional strategies such as incentivizing land conservation and a groundwater allocation market.

The County GSAs' implementation plans include a gradual transition to sustainability by 2040. This allows time for the County GSAs to study, develop, finance, and build capital projects, and to develop monitoring, measurement, and enforcement programs. It also provides time for current groundwater users to

[1] Average consumptive use values using actual historic land use conditions between 1989 and 2014 were estimated to be lower than estimates that assumed a static 2015 land use as if it were in place during this same entire period.

implement demand management programs to limit groundwater consumption. Reductions in consumptive use of water will be made over the 20-year timeline, seeking to reduce the previously noted exceedance of groundwater by a rate of 2% per year for the first five years and then 6% per year thereafter, until sustainability is achieved.

While the County GSAs are working to reduce adverse effects associated with SGMA compliance, reducing consumptive use of groundwater will impact many agricultural users and have ripple effects across the local economy. Growers in the San Joaquin Valley have depended on groundwater pumping to support their agricultural livelihood for decades. Approximately half of the Madera County economy and one in three jobs is linked to Madera County agriculture (ERA Economics, 2020).[2] In 2019, Madera County GSA commissioned a study that examined the economic impact of groundwater use reductions in the area managed by Madera County within the Madera Subbasin (Madera Subbasin Joint GSP Appendix C, ERA Economics, 2020). Direct economic impacts (e.g., changes in irrigated acreage and associated revenues) occur in the Madera Subbasin as a whole and regional multiplier effects (e.g., changes in farm labor income) occur in the broader Madera County area.

The impact assessment found that the demand management program outlined in the Madera Subbasin Joint GSP would require the idling of 28,400 acres (approximately 13% of current irrigated acreage), causing direct farm revenue losses of $130 million per year. Water use reductions would result in a gradual fallowing of land – averaging an additional 1,350 acres every year. Additionally, full time jobs in the County would decrease by approximately 575 per year (including direct, indirect, and induced jobs), with wage income falling by $52.9 million annually. This equates to between 1,200 and 1,800 seasonal jobs in Madera County; many of these jobs and income support disadvantaged communities (DACs) in the county. Finally, Madera County tax revenues would fall by approximately $1.4 million per year by 2040 (~3.3%). The loss in tax revenue reflects local revenue to the County, so local services provided by these agencies might be impacted as revenues fall. As an important note, the economic study assumes an optimized outcome, meaning that water is transferred to its highest value use within some bounds (as specified within the economic model). This approach results in outcomes similar to those that might expected with a market or similar mechanism for transferring allocations across parcels. Without this flexibility, individual growers may not be able to achieve these optimal outcomes.

2.2 Potential Role of Water Market in Madera County

SGMA offers GSAs significant flexibility to tailor management activities to best meet local needs. This includes the ability to assign groundwater allocations (e.g., a set amount of water per acre or irrigated acre) to groundwater users and to authorize transfers of these allocations. In this way, SGMA opens the door for local groundwater markets that can facilitate the transfer of groundwater allocations from willing sellers to willing buyers using appropriately structured market mechanisms.

A market-based approach can offer several benefits compared to a strict allocation method where landowners are only able to pump and use a set amount of water on a parcel-by-parcel basis. Markets allow users to reallocate limited groundwater resources to the highest value uses; this can lessen the economic impacts of temporary shortages and support long-term shifts in water use patterns. In addition,

[2] Madera Subbasin Join Groundwater Sustainability Plan, Appendix C (ERA Economics, 2020). Available: https://www.maderacountywater.com/wp-content/uploads/2020/02/Madera_Appendix3_Final_2020.pdf

market participants can often sell or lease their allocations for a higher value than they could earn if they put to use on the original parcel to which it was assigned. This allows limited groundwater resources to not only be used in more valuable ways while compensating the original owner.

Another benefit of a groundwater market is that it offers more flexibility and autonomy to stakeholders in making decisions that directly affect their business. Markets can also incentivize water conservation and investment in water efficiency technologies, as well as new infrastructure such as groundwater storage. For example, Ayres et al. (2021) note that trading can incentivize formal groundwater banking projects that store water underground on behalf of specific parties. This is an important supply augmentation and risk management strategy that will likely prove key for SGMA implementation.

While markets have the potential to offer additional benefits, they can also have unintended or incidental effects on third parties or the environment. When a trade is made, sellers forego pumping while buyers pump the groundwater they have purchased (i.e., the water is not pumped from one location and conveyed to another for use). This change in the location of where groundwater pumping occurs can result in adverse effects if it results in increased pumping or continued overdraft pumping in areas of concern (e.g., areas located near at-risk domestic wells or in areas of high subsidence). Similarly, allowing for carryover of an annual allocation to a subsequent year(s) can have temporal impacts, especially in years of drought where large amounts of carryover could be pumped in one year. Water quality and total extraction quantity concerns are also important to address early in the planning phases. Potential adverse effects can be minimized through intentional protections and market rules. This is discussed in more detail in Section 5.

3. Stakeholder Engagement – Overview and Key Findings

There are several enabling conditions and key elements that must be in place to ensure the success of a local groundwater market. Chief among these is the support of key stakeholders, including market participants and other potentially affected parties. Without input and buy-in from these groups, it will be difficult for a market to gain traction. The WaterSMART Water Market Strategy grant incorporated significant stakeholder outreach, including initial one-on-one stakeholder interviews and three strategic workshops (Figure 2) held over the course of 2020. This section provides an overview of the stakeholder process, as well as key findings and outcomes.

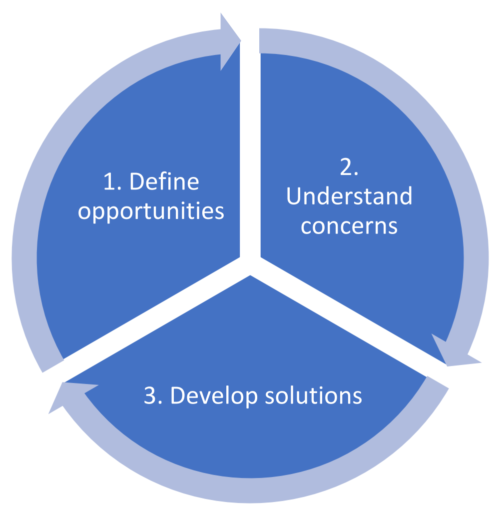


Figure 2. Outreach and engagement strategy

3.1 Stakeholder Interviews

The consultant team conducted interviews with key stakeholders through phone, email, and in-person meetings to build relationships across organizations. Interviewees included representatives from the Chowchilla and Madera subbasin GSAs, disadvantaged communities (DACs, including representatives from Self Help Enterprise and the Leadership Council for Justice and Accountability), Madera Ag Water

Association, Cattlemen's Association and Farm Bureau, resource conservation districts, water companies, and relevant County officials. In total, the team conducted 12 interviews in early 2020. The interviews gauged the level of knowledge of water market strategies in general and inquired about support for a market-based solution to managing water demand. Input was solicited on opportunities, challenges, affected parties, and anticipated impacts.

Overall, most interviewees supported a groundwater market pilot program as a general concept but expressed only a cursory understanding of the complexities of market tools. Concerns were voiced around transparency, anonymity, and equity of the market structures, rules, and trading process. Partners were vocal about the potential impacts on communities that rely on groundwater for drinking water supplies, especially those that are economically disempowered, and expressed the need for additional tools to reduce water consumption. Most participants were challenged to offer ideas for mitigating negative impacts given the early stage of market development, and broadly encouraged ongoing education of and support from the majority of stakeholders before moving forward. Input received during these initial interviews informed the outreach leading up to subsequent workshops, as well as the content of workshops. Appendix A contains a complete summary of the findings from these early partner interviews.

3.2 Workshops/Meetings

After conducting individual interviews, the project team held a series of three workshops for the larger community that would be impacted by changing groundwater demand management. The workshops served to present information and to promote understanding of water markets as well as to gather information on concerns, opportunities, and perspectives of implementing a water market in Madera County. The workshops successively built knowledge and gathered increasingly complex feedback from the community regarding concerns with specific elements of water markets. Summaries of each workshop including participant information and detailed feedback is available in Appendix B. The presentations from these workshops are also included.

Workshop 1 – Defining Opportunities[3]

The initial workshop was held in person at the Madera County offices in Madera, CA on February 25, 2020. It was attended by 43 participants in addition to County staff and members of the consultant team. The objectives of this meeting included:

- Introduce water market concept, tools, and context
- Identify and discuss partner opportunities, constraints, and concerns
- Initiate discussion on affected parties and impacts
- Gain insights and begin to brainstorm for future partner discussions

The County reviewed the concept of water rights within the context of markets and described reasonable and beneficial use and surface and groundwater differences, per the California State Water Code. Corona provided an overview of groundwater markets, potential benefits, and rules and strategies for reducing adverse effects or unintended consequences. Corona also presented an overview of the groundwater market recently established by the Fox Canyon Groundwater Management Agency in Ventura County, CA.

[3] Madera County Water Market Workshop #1. February 25, 2020. Agenda, summary and presentation available: https://www.maderacountywater.com/water-markets/

Attendees participated in an interactive mapping exercise to identify geographical concentrations of opportunities and challenges.

Key questions raised in the workshop included how the County would set, manage, and track tradeable allocations and year to year carryover amounts. There was also an extensive discussion among participants regarding finding the appropriate balance of transparency and confidentiality of water sales, quantities, and prices. There was some concern that larger growers would be able to monopolize the market and that small agricultural operations would not fare well in a market system. The authority of the County to monitor and enforce compliance, as well as to administer an accounting system, was also questioned. Some workshop participants were concerned with allocations to irrigated and non-irrigated lands; others voiced concerns regarding the potential for water supply/quality impacts to domestic and municipal wells if pumping were increased or concentrated in areas where wells are located.

At the same time, many agreed that a market could provide significant opportunities, including incentivizing groundwater recharge and conservation, helping to maintain the viability of permanent crops while providing income to those who choose to sell their allocations, providing short-term flexibility to growers, and creating incentives and rules to reduce pumping in areas of concern (e.g., areas around domestic or small community wells, groundwater dependent ecosystems, and areas of high subsidence).

Workshop 2 – Understanding Concerns[4]

Due to the Covid-19 pandemic, the second workshop was held virtually on April 19, 2020. Close to 100 participants attended the virtual meeting, in addition to County staff and members of the consulting team. The primary objectives for the meeting were to:

- Share information on groundwater allocations under water markets and SGMA regulations
- Provide an overview of water market strategies and solicit partner feedback through online polling and written feedback
- Discuss next steps and partner solutions workshop

The session began with an overview of the County's efforts to establish groundwater allocations to help achieve sustainable yield within the County GSAs. Presenters explained how allocations fit within the context of SGMA and water markets. They also reviewed additional initiatives/tools that the County GSAs are exploring to further demand management. Corona presented an overview of "market basics" including key prerequisites, the potential role of a groundwater market in Madera County, and potential strategies for reducing or avoiding adverse effects.

For the remainder of the workshop, the consultant team focused on using online survey questions and encouraging written feedback (via the webinar chat function) on four key aspects of market design, including: 1) rules and strategies for reducing potential adverse impacts associated with trading (e.g., rules to protect domestic wells and other concerns identified in Workshop 1); 2) rules related to carryover of allocations for use in future years; 3) market exchange methods/platforms; and 4) issues and concerns regarding participant anonymity and confidentiality.

[4] Madera County Water Market Webinar #2. April 19, 2020. Agenda, summary, video recording and presentation available: https://www.maderacountywater.com/water-markets/

Feedback offered ranged across participants. In general, participants seemed supportive of putting rules in place to protect domestic and municipal wells. Some expressed concerns over prohibiting the resale of water once purchased, as well as a desire to be able to tap into or purchase future allocations. There seemed to be strong support for allowing carryover of allocations in the context of a market, with reasonable limitation. Several participants had questions about how groundwater use would be monitored, and rules enforced. One point of agreement was on the method for market exchanges – the majority of participants showed support for the use of an electronic "smart market" for matching buyers and sellers (described in more detail in Section 5). Feedback relating to market transparency was somewhat mixed – many felt that information on individual trades should be made publicly available (e.g., volume traded, price, in some cases information on buyers and sellers), while others felt this information should only be reported in aggregate and that information on individual buyers and sellers should not be disclosed.

Workshop 3 – Developing Solutions[5]

The final workshop, also held virtually, took place on December 1, 2020. Key objectives included:

- Review outcomes from previous partner engagement
- Share results of the water market impacts analysis
- Present market structure and rules for pilot program
- Provide overview of pilot project process and recruit participants.

The project team incorporated feedback from the previous two workshops to develop a structure for a pilot groundwater trading program. The goals and key tenets of the pilot project were presented, including market structure, potential market rules, and the process for facilitating market exchanges. Wood Rodgers also presented a geospatial analysis of potential water market impacts and strategies for offsetting any adverse effects (discussed in detail in the next section). The workshop was also used to recruit potential participants for the simulation of a water market, a yearlong project that required significant participant feedback.

Many participants expressed a strong desire for allowing larger carryover amounts/period and multi-year trades to help provide flexibility in drought years. Several also advocated for allowing trading of transitional water (a term unique to the County GSAs' allocation approach) as a way to generate initial supply in the market itself. Feedback was also provided on any aspects of the market participants found confusing and where additional information could help participants make better decisions. Comments showed some participants to be optimistic about the information that could be gathered from engaging stakeholders in a market simulation.

4. Key Considerations for a Groundwater Market in Madera County

This section provides an overview of key market considerations specific to Madera County, including:

- The County's method for assigning individual groundwater allocations to landowners within the County GSAs
- Compliance, monitoring, and enforcement procedures

[5] Madera County Water Market Webinar #3. December 1, 2020. Agenda, summary, video recording and presentation available: https://www.maderacountywater.com/water-markets/

- Legal considerations
- Understanding any potential adverse effects, and identifying rules to offset anticipated impacts

These different factors influence what is possible in terms of market structure and design in Madera County.

4.1 Background and Existing Markets

Groundwater markets are not a new concept in California; however, according to the Public Policy Institute of California (PPIC, 2021), groundwater markets have been slow to develop in the state because tradable groundwater allocations are still rare. A handful of adjudicated basins—where such allocations do exist—have adopted water market strategies. For example, in 1996, the Mojave Groundwater Basin established a “cap-and-trade” system and groundwater market to provide flexibility to agricultural growers in meeting groundwater use restrictions. Today the market is one of the most active water markets in the U.S. and is credited with stabilizing groundwater levels in the Basin. Several other successful surface water and groundwater markets have been established in other areas of California and throughout the country.

The onset of SGMA has heightened interest in groundwater markets in high- and medium-priority basins(as designated by DWR). The Fox Canyon Groundwater Management Agency in Ventura County is credited with establishing the first SGMA-related groundwater market. While the market was a bit slow in its initial year of implementation, it is now experiencing successful trades. In the Borrego sub-basin, located in eastern San Diego County, groundwater pumpers reached an agreement in early 2021 on a new system that includes a market. Interest reportedly continues to grow in other basins (PPIC 2021).

A review of existing water markets provided insights into the analyses and proposed design of a potential groundwater market in Madera County (see Appendix C for lessons learned and key elements associated with select water markets). The structure and rules of existing markets varies considerably based on local conditions and management objectives. Several markets report that it is essential to have accurate water use data to ensure compliance in a water market; in addition, the goals and rules of a water market should be tailored to participants’ interests and needs. In learning about how rules are established, it is often best to start with minimal and simple rules and to adaptively manage the program over time to implement rules and trading restrictions as needed. Finally, the development of a market requires significant agency, stakeholder, and technical expertise, so pilot programs were widely utilized before adopting market-based strategies.

4.2 Sustainable Yield and Groundwater Allocations

Key prerequisites to a functioning groundwater market include 1) the development of an allocation system that establishes the amount of groundwater each landowner or pumper will be allowed to extract from the basin for consumptive use or transfer to other users, and 2) an accounting system that measures and tracks the use of allocations. This section provides an overview of Madera County GSA’s allocation system. Section 4.3 describes the County’s approach for measuring and tracking the allocations.

Allocations are designed to protect the groundwater resource, collectively amounting to a cap on total consumptive use of native groundwater resources (i.e., sustainable yield). Without a strict adherence to fixed allocations, a cap-and-trade style water market will not function because users will be able to continue pumping water in excess of sustainable use.

As described above, the GSPs adopted for the Madera, Chowchilla, and Delta-Mendota subbasins establish the level of groundwater consumptive use that will be required to reach sustainable yield by 2040. This represents the total cap. On June 8, 2021, the County GSAs adopted a strategy for allocating this total amount across irrigated acres within the County GSAs for the Madera, Chowchilla, and Delta-Mendota subbasins. This allocation approach uses two designations of groundwater access:

1. Sustainable yield, which is tied to the overall sustainable yield of each subbasin, such that if land users consumed the maximum groundwater allocation for every eligible acre, the subbasin would still achieve sustainable yield.
2. Transitional water, which is a continued quantity of consumptive use that exceeds sustainable yield (i.e., overdraft). Transitional water availability will incrementally decrease over the 20-year implementation period until reaching zero. This is when sustainable yield is reached.

The allocation approach provides a per-acre allotment of sustainable yield and transitional water to participating eligible parcels. The baseline quantity for the allocations is the average evapotranspiration of applied water (ETAW) within each County GSA, rather than total groundwater extracted. This method for quantifying allocations is a direct result of the method used for measuring water use (see Section 4.3). The approach for determining per-acre sustainable yield allocations will remain consistent over time while per-acre transitional water allocations will decrease in availability every year until no transitional water is available by 2040.

Each year, eligible parcels will receive a designated quantity of sustainable yield and transition water. Eligible parcels include those with currently irrigated acreage (as of June 8, 2021) or that were last irrigated as recently as January 1, 2015 but that have been fallowed or idled since that time. Parcels that are part of an active irrigated agricultural operations or permitted confined animal operations are also eligible to receive an allocation of sustainable yield and transition water. Lands that are not categorized as irrigated, using the parameters discussed above, may opt-in for an allocation of sustainable yield for acres being put into active irrigated agriculture for sustainable yield only, as demonstrated to the satisfaction of the County GSA.

The per-acre allocations allow for both sustainable yield and transition water to be used flexibly across eligible parcels and shared across parcels within a designated farm unit. Farm units represent groups of parcels that are collectively managed and located in the same farm unit zone (see Figure 3). The purpose of farm unit zones is to limit potential adverse effects associated with the transfer of allocations among parcels in different zones. From a practical operations perspective, the farm units provide functions similar to a partial groundwater market in that an allocation can be shifted from one parcel to another to facilitate flexibility for the operator of a farm unit so long as those parcels are within the same zone.

At this juncture, the allocation approach applies to County GSAs only, with other GSAs planning to manage their portion of sustainable yield differently.

4.3 Compliance, Monitoring, Tracking and Enforcement

Reliable measurement, reporting, tracking and enforcement procedures are essential to establishing trust in market transactions (PPIC 2021). All water users must trust that the system is accurately measuring and tracking water. For example, it is key to ensure that a seller is only selling water to which they have valid rights or have been authorized an allocation of use, and not water that belongs to another party. It is also important to ensure that growers are not using more water than they have purchased and/or has been allocated to them. Lessons learned from other markets indicate that enforcement procedures must be sufficiently severe to encourage market participation.

Within the County GSAs, monitoring of evapotranspiration (ET) and ETAW will be done with remote sensing methods, using satellite technology, provided by IrriWatch using SEBAL (Surface Energy Balance Algorithm for Land). Quality assurance and quality control will be performed by IrriWatch, Davids Engineering, and Madera County staff.

4.4 Legal Statute

SGMA provides the legal statute that allows GSAs to control extractions by "establishing groundwater extraction allocations." (Water Code, § 10726.4, subd. (a)(2).) GSAs also have the authority to "regulate groundwater extraction" by "authoriz[ing] temporary and permanent transfers of groundwater extraction allocations within the agency's boundaries." (Water Code, § 10726.4, subd. (a)(3).)

4.5 Analysis of Supply and Demand and Potential Adverse Effects

To assess the potential for a groundwater market in Madera County, the consultant team examined the distribution of irrigated acreage by crop type within each farm unit zone. This analysis examined overall supply and demand in the market, as well as the potential for changes in the location of pumping within individual subbasins (and any associated adverse effects). The project team also assessed the potential for concentrated pumping to occur in areas of concern as a result of market trades. To conduct these analyses, the project team used historical crop data and analyses conducted for the relevant GSPs. The section presents the results of these analyses and discusses the potential implications for if a groundwater market were to be implemented.

4.5.1 Distribution of market supply and demand across farm unit zones

Table 1 shows total irrigated acres, by crop type, within the portions of the Madera and Chowchilla subbasins that fall within the County GSAs. In the initial years of the market, crops that are "more likely to buy" include perennial, high value crops (e.g., citrus, nuts). As shown below, these crops make up a relatively high percentage of total irrigated acreage in both subbasins. Crops considered "more likely to sell" groundwater allocations include annual crops that have a lower return to water (e.g., corn, grains, hay, pasture, and alfalfa). While in many cases, the crops identified as "more likely to sell" will serve as an initial source of supply for the market; this is not to say that all growers of these crops will elect to sell their groundwater allocations. For example, some of these crops are tied to dairy nutrient management plans, while others serve as an important local feed source and/or cannot easily be fallowed without affecting overall farm operations.

Table 1. Distribution of irrigated acreage within County GSAs

	Madera subbasin, County GSA		Chowchilla subbasin, County GSA	
	Acres	**% of total**	**Acres**	**% of total**
Almonds	35,961	40%	13,430	37%
Citrus and Subtropical	1,622	2%	11	0%
Corn	5,038	6%	7,331	20%
Grain and Hay Crops	6,202	7%	2,805	8%
Grapes	16,569	18%	4,877	13%
Miscellaneous Deciduous	1,092	1%	259	1%
Miscellaneous Field Crops	163	0%	399	1%
Miscellaneous Truck Crops	2,120	2%	819	2%
Pasture and Alfalfa	3,260	4%	3,850	11%
Pistachios	18,446	20%	2,726	7%
Walnuts	472	1%	0	0%
Idle	941	1%	49	0%
Total	**90,947**		**36,508**	

Source: Annual Land Use Time Series for GSAs based on County Land Use Data, 2019

Further analysis of irrigated acreage within the Madera subbasin portion of the County GSA indicated the following:

- Crops that fall within the "more likely to buy" category are distributed across the three farm unit zones relatively proportional to how overall irrigated acreage is distributed. This makes it more likely that the demand for groundwater allocations will be somewhat evenly distributed across the GSA (relative to existing distribution of irrigated acreage), rather than concentrated in any one area/zone. This makes it difficult to predict where increased pumping would occur as a result of market trades because individual circumstances will dictate who decides to buy water on the market.
- Crops that fall within the "more likely to sell" category are more concentrated in the West Farm Unit Zone (Figure 3).
- The demand for groundwater allocations from higher value and perennial crops (i.e., more likely to buy) will be greater than the supply available from annual crops and crops that have a lower return to water (i.e., more likely to sell). Specifically, the ratio of irrigated acreage that falls within the category of "more likely to buy" versus "more likely to sell" is close to 3. In addition, if growers are only allowed to sell to buyers located within the same farm unit zone, more demand will go unmet in the East Northern and East Southern zones due to lack of supply (i.e., the concentration of crops that are more likely to sell in the West farm unit zone).

For the Chowchilla subbasin portion of the County GSA:

- Overall, the ratio of irrigated acreage that falls within the category of "more likely to buy" versus "more likely to sell" is less than 1, meaning it is likely that there will be an adequate supply of groundwater allocations for the market.

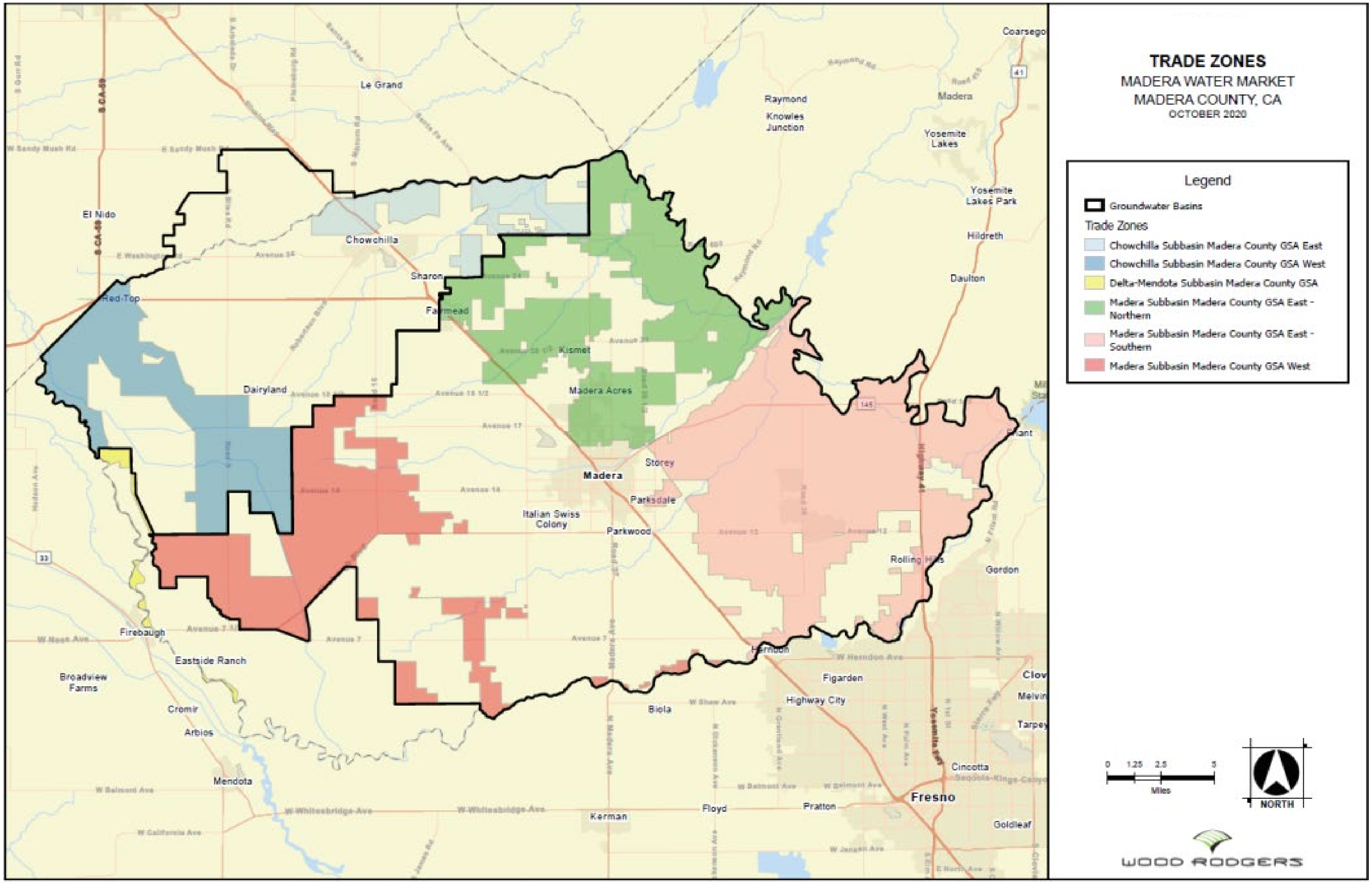


Figure 3. Madera County farm unit zones

- This varies by farm unit zone. The West Chowchilla farm unit zone contains a higher percentage of the irrigated acreage that falls within the "more likely to sell" category; in this zone, the ratio of irrigated acreage that falls within the "more likely to buy" vs. "more likely to sell" categories is 0.7. The East farm unit zone has a buy to sell ratio of 1.8, indicating a higher level of demand relative to initial supply. Thus, more sales would be expected to come from the West farm unit zone, with more pumping of the marketed allocations occurring in the East farm unit zone (if trading was allowed to occur across zones).

In the Delta-Mendota portion of the County GSA, there is a relatively even split between crops that are more likely to sell versus buy. However, there is a relatively small number of irrigated acres overall.

4.5.2 Analysis of potential adverse effects due to changes in the location of pumping

The project team also evaluated whether there are areas of the County GSA where continued (or increased) consumptive use of groundwater has the potential to adversely affect the following areas by further lowering groundwater levels:

- Domestic, municipal, and other water supply wells
- Local surface waters and associated habitat, also referred to as groundwater dependent ecosystems (GDEs) [6]
- Areas with high potential for increased land subsidence

Figure 4 shows areas located within the Madera, Chowchilla, and Delta-Mendota subbasins where the potential for adverse effects may exist. Each area includes a one-mile buffer area around it. The project team examined irrigated acreage within each buffer area by crop type. This allowed us to evaluate the extent to which growers in these areas are more likely to buy (to maintain current consumption rates as allocations quantities decrease) or sell allocations and the resulting (potential) effects on groundwater levels. It also allows us to examine the potential effect of limiting groundwater purchases within these areas (in some way). Key findings of this analysis include:

- In the Madera subbasin portion of the County GSA, a relatively small portion of crops that are "more likely to buy" fall within the areas identified as having a higher potential for surface water interaction/GDEs or subsidence. Further, these areas contain a higher percentage of potential sources of supply, when compared to the overall basin. Again, when a parcel or farm unit is a source of supply, less groundwater is pumped from that parcel or farm unit. This high-level analysis indicates that a market may result in limited impacts and even positive outcomes related to subsidence and GDEs in the Madera Subbasin portion of the County GSA.

- Conversely, approximately 31% of the "more likely to buy" crops fall within the identified buffer areas for domestic wells and municipal wells, while 17% of supply crops fall within these areas. The buy to sell ratio is more than 5, compared to approximately 3 for the overall basin. This indicates that subject to monitoring of groundwater levels and market transactions, rules to limit market purchases that would result in increased pumping in these areas may be warranted.

[6] Modeling conducted for the GSPs indicate there is no hydraulic connection between regional groundwater and streams in the Madera and Chowchilla subbasins. The team analyzed the areas around the San Joaquin River to better understand the sustainable yield allocations that might be sold from within this area, which would potentially augment groundwater levels.

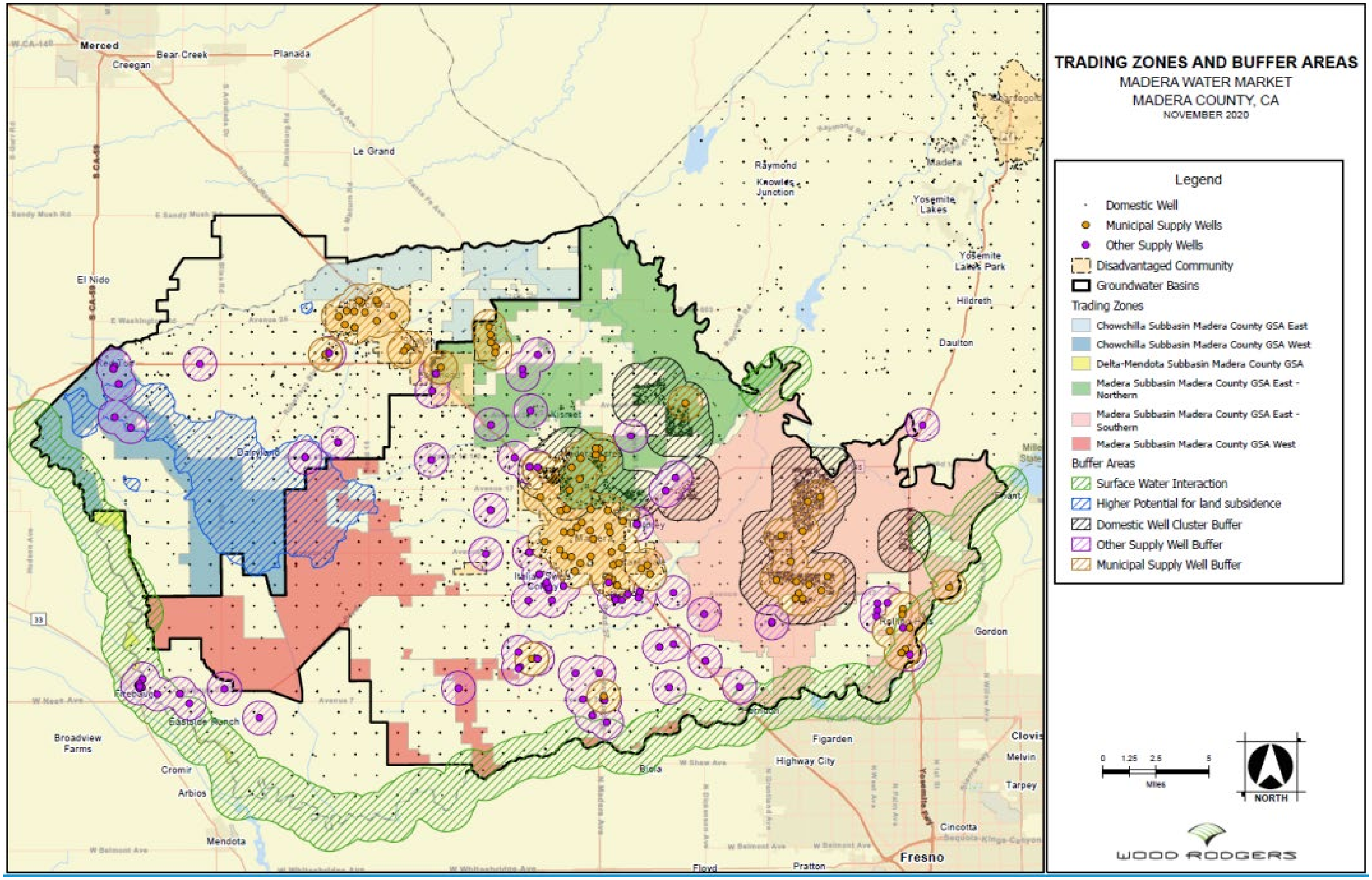


Figure 4. Buffer areas to protect wells, subsidence prone areas and surface water sources.

- In the Chowchilla subbasin portion of the County GSA, more irrigated acreage classified as "more likely to sell" falls within the potential GDE and subsidence buffer areas compared to irrigated acreage classified as "more likely to buy." This means that there more groundwater could be left in the basin in these areas as pumping of allocations would be transferred to a buyer located elsewhere.
- Slightly more irrigated acreage within the municipal well buffer areas falls within the "more likely to buy" category in the Chowchilla portion of the County GSA. However, irrigated acreage within these areas account for a relatively low percentage of total irrigated acreage within the subbasin (13% and 10% of likely to buy and sell, respectively). The ratio of "more likely to buy" to "more likely to sell" crops indicates that there is a chance for continued or increased pumping from these areas. This again indicates the need for market rules to limit this outcome, subject to monitoring of groundwater levels and market transactions.
- Most of the irrigated acreage within the Delta-Mendota subbasin portion of the County GSA fall within area that has the potential for surface water interaction/GDEs.

4.5.3 Summary of potential impacts and related market implications

In the Madera subbasin, a much higher proportion of irrigated acres fall within the "more likely to buy" category compared to the "more likely to sell" (i.e., initial demand will likely be much greater than initial supply). Some growers of higher value crops will likely begin to sell their allocations as it becomes in their best economic interest to do so. It is impossible to predict where these growers will be located, as this decision depends on individual circumstances.

Based on the existing distribution of crops, it is likely that the demand for groundwater purchases will be distributed relatively evenly across the County GSAs, rather than concentrated in a specific area(s). In both the Madera and Chowchilla subbasin portions of the County GSA, likely sources of supply are more concentrated in specific areas of the subbasin. However, as noted above, not all growers of crops that are in the "more likely to sell" category will sell their groundwater allocations.

In the Madera subbasin, the buffer areas around municipal and domestic wells contain a relatively high percentage of crop types that fall within the "more likely to buy" category. In the other buffer areas identified (in both subbasins), there is a higher percentage of crops that are "more likely to sell" allocations compared to the overall subbasin. This could result in positive effects and/or support rules that limit buyers located in buffer areas to purchasing allocations from sellers located within the same buffer area.

While analysis of the distribution of different types of crops helps to provide an indication of where potential sources of supply and demand are located, it does not provide an exact prediction of where or how many trades will occur. For reasons outlined above, there is uncertainty as to where buyers and sellers will be located. Rather than adopting rules at the outset to mitigate against potential adverse effects, lessons learned from other markets indicate a need for more adaptive management and monitoring over time. The GSPs include sustainability indicators and minimum thresholds for groundwater levels and groundwater quality that will be continually monitored. Rules can be triggered, or trades limited if the need is indicated by these monitoring efforts.

5. Pilot Market Simulation

Following the extensive research, analyses, and stakeholder engagement efforts described above, the project team initiated a year-long "virtual" pilot groundwater market simulation program. This section describes the pilot market simulation program, including its key objectives, methodology, the general structure and rules of the market, and key findings and results.

5.1 Overview and Objectives

The pilot program was executed over nine months, with each month representing one year/irrigation season. The design and structure of the pilot market were driven by the feedback received during outreach efforts described in Section 3. Objectives of the pilot included:

- Simulate multiple years of trading under different conditions.
- Test market structure, potential rules, and administrative processes.
- Understand participant decisions under different conditions.
- Obtain participant feedback.

The pilot market allowed farmers and agricultural growers within the County to buy and sell groundwater allocations, subject to market rules and limitations. Each simulated year, participants were provided information on their irrigated acreage, sustainable yield allocations, the quantity of transitional water available to them, the farm unit zone in which their farming operation was located, and other relevant factors. Based on this information, participants provided input on how they would manage their crops in response to decreased groundwater availability, as well as whether they would like to buy or sell water on the market. They also provided feedback on key elements of market design and the pilot process.

Transitional water allocations decreased each month for the first seven months until transitional water was no longer available in the final two months of simulation. The water year classification (i.e. wet, average, or dry years) varied across the simulation periods. Rules, fines, and incentives were introduced in later rounds to determine their effect on participant behavior (Table 2). Each round, administrators applied a matching algorithm to match buyers and sellers (anonymously) and published aggregate information on trades each month. Aggregate trading results and individual results were provided to participants following each round.

5.2 Methodology and Logistics

Through the GSP process and subsequent workshops related to the potential groundwater market, the County has developed an extensive network of stakeholders. The County recruited participants for the pilot from this existing network. Agricultural growers who own lands located within Madera County were eligible to participate in the pilot market regardless of whether they farmed land within the County GSAs or in other GSAs. Invitations to participate were also extended to ranchers and other key stakeholders who engaged in the workshops.

Each participant was assigned characteristics that they assumed for their role as a grower in the pilot market (e.g., irrigated acres by crop type, farm unit zone, groundwater allocations, crops grown in buffer areas). As applicable, this information was closely matched to the actual characteristics of participants. However, participants were provided an ID so that their market participation and cropping decisions would remain publicly anonymous. A total of 68 participants agreed to join the pilot project. They were

Table 2. Simulated conditions each round of pilot

Pilot Round	Sustainable yield allocation per irrigated acre	Transition Water per irrigated acre	Rainfall year type	Carryover Allowed	Rules (implemented continuously once introduced)
Round 1	0.75	1.75	Normal	1 years' worth of SY allocation	Cannot buy transition water and sell water in the same year
Round 2	0.75	1.55	Normal	1 years' worth of SY allocation	
Round 3	0.75	1.35	Normal	1 years' worth of SY allocation	Trading limited to within County and within subbasins
Round 4	0.75	1	Dry	1 year's worth of SY allocation	
Round 5	0.75	0.75	Dry	2 years of SY	Increase allowable SY Carryover from 1 to 2 years' worth of groundwater
Round 6	0.75	0.5	Dry	2 years of SY	
Round 7	0.75	0.25	Wet	2 years of SY	\$600/AF incentive to fallow land in buffer area
Round 8	0.75	0	Normal	2 years of SY	\$200/AF penalty for water purchased to irrigate land in buffer area
Round 9	0.75	0	Dry	2 years of SY	

assigned crops in proportions representative of the actual cropping patterns in the Chowchilla and Madera County GSAs (with the Delta Mendota subbasin folded into the Chowchilla). The total acreage of the pilot represented approximately 68% of the total irrigated acreage within the County GSAs.

Each month of the pilot, participants received an information packet containing key information for that trading year or round. Table 3 shows an example of a key data table included in the information packet for an anonymous participant from Round 2. To ensure that the information presented in the table was not interpreted as decisions or policies that the County has made with respect to the market (rather than decisions or policies being tested), the project team highlighted all hypothetical information in yellow.

In addition to this table, the project team provided a table to participants showing their irrigated acreage by crop type going into the current round. This table reflected any changes participants made to their irrigated acreage in the previous round. The table also included consumptive use demand (ETAW) by crop type and typical revenues and costs per acre. Participants were instructed to use the ETAW estimates to determine how much water they would need for that simulation year (after accounting for any deficit irrigation). ETAW estimates varied by rainfall year type, as crops require more water in dry years and less water in wet years. The estimates were based on data from the GSP.

Table 3. Participant Information for Trading Simulation #3 (Year 3)

Participant ID	MW5555	This is the number assigned to you for tracking your responses/participation each month.
Irrigated acreage in your farm unit	140 acres	This is the irrigated acreage by crop type that you are to assume for this trading simulation for your farm unit.
Subbasin/farm unit zone	Madera West farm unit zone	Farm unit zones are zones identified by the County within which individuals can form farm units - groups of parcels owned by the same person or entity. Water use can be managed flexibly across parcels within a farm unit zone.
Buffer areas	20 acres almonds – Well buffer area	These are areas where the County will be monitoring groundwater levels for any potential impacts related to municipal and domestic wells, subsidence, and/or potential surface water interaction. For this simulation year, there are no rules in place related to identified buffer areas. The County will continue to monitor market activity associated with lands in identified buffer areas.
Idle or rangeland acreage	40 acres idle	Idled land is land that has been irrigated within the past 3 years but is not currently irrigated. You will receive a SY allocation for these lands. You can use this allocation within your farm unit, sell it, and/or carry it over into the next year. For participants with non-irrigated rangeland, you will receive SY allocations for that rangeland. You cannot sell SY allocations associated with your rangeland.
Sustainable Yield (SY) Allocation	0.75 acre feet (AF) per acre	This is the hypothetical SY allocation available this year based on the total available divided by the total number of acres that opted in. You can choose to sell or use this water. You can carryover up to 1 year of SY allocation for use or sale into the next year.
Carryover from previous year	30 AF	For the first trading simulation, assume no carryover amount is available for use. You can carry over up to 1-year's worth of SY allocation into next year. This includes groundwater allocations purchased on the market and any transitional water purchased. Total carryover cannot exceed the SY allocation amount from previous year.
Maximum transition water available.	0.75 AF/acre at $200/AF	The County GSAs will be making "transitional" water available to growers for a fee. The amount of transitional water available will decline over time as we progress towards SY in 2040.
Rainfall	Normal year (average rainfall)	The consumptive use demand for your crops (provided below) represents the consumptive use demand over and above what is met through precipitation for a normal (average) rainfall year. We will vary precipitation and associated consumptive use demand over the course of the pilot.
Penalty for using more groundwater than allocated to you	$1,500/AF	If the County determines that your use has exceeded your total consumptive use demand, you will be charged an additional fee per AF for the additional groundwater used. County will compare the consumptive use demand for the irrigated crops you report to the total amount of water you have available (i.e., transitional, SY allocations, groundwater purchased from market).
Additional market rules/conditions	**Minimal rules:** Trading limited to individual subbasins. Water cannot be sold for use on lands outside of the County. You cannot buy transition water and sell your SY allocations in the same year.	For this trading simulation, minimal rules are in place. Different market rules will be tested over the course of the pilot. These may include trading restrictions related to farm unit zones and/or identified buffer areas.

To help participants estimate the effect of changes in cropping patterns and inform their decisions with respect to market participation, the project team utilized crop cost and return studies published by University of California Davis and applied the most recently published studies from the closest geographic region. Product prices were also available in these studies; however, the project team relied on the Madera County Annual Crop Reports for per acre crop values to estimate revenues associated with different crop types. Participants were cautioned that the typical costs and revenues presented were intended to be used as a guide in making decisions but that, when possible, they should rely on cost/revenue data that reflects the actual conditions at their farm. Table 4 shows an example of the table participants received with this information, for an example participant from Round 3.

For participants with nut trees (pistachios, walnuts, and almonds), tree age was taken into consideration when applying ETAW estimates, as consumptive use demand changes as trees age and come into production. The project team provided participants with an initial age distribution for their treed acreage, as well as the corresponding consumptive use. Each round, participants reported changes to their tree age distribution (e.g., if they ripped out old trees and planted new ones). Otherwise, trees were automatically aged over the course of the pilot.

Finally, participants were provided with the total sustainable yield amount they had available for use across their farm unit(s) in the simulated year, the maximum amount of transition water available to them, and the total consumptive use demand of applied water associated with their irrigated acreage. Using this information, participants let us know how much groundwater they would like to buy or sell (if applicable) and submitted their irrigated acreage by crop type (and other management actions such as deficit irrigation), reflecting any changes they made in response to decreased water availability. Participants who wanted to buy water were also asked what changes they would make to their irrigated acreage if they did not receive the full amount of water that they wanted to purchase. Participants were instructed to assume that they did not have access to surface water for irrigation purposes.

In addition to the information packet, the project team developed an Excel workbook with information on consumptive use demand by crop type (including for younger trees), typical costs and revenues for different crops, and other key decision inputs. Participants could enter their irrigated acreage into the spreadsheet to determine how much water they would need and how profitable their operation would be based on their cropping and market decisions.

To accomplish the exchange of information between the pilot administrators and participants, the project team utilized Google Forms, which deposits participant responses to a Google spreadsheet. Based on the information provided to them, participants would report their decisions and activities each round. Participants would enter their ID in the Google Form and fill out fields/respond to questions related to the key topic areas outlined in Figure 5 below. Each month, administrators would aggregate participant responses by analyzing their decisions, updating a database with current cropping patterns, matching trades of groundwater allocations, calculating overall changes in transitional water demand, and aggregating changes in consumptive use and irrigated acreage across the entire simulated management area.

Table 4. Irrigated/Agricultural Acreage by Crop Type for Your Farm Unit (For Purposes of Trading Simulation)

			To be used as guide; please consider revenues/costs as appropriate for your farming operations; Rangeland revenues/costs not available.		
Crop type	Irrigated/ agricultural acres: Trading Simulation Year 3	Consumptive use demand (evapo-transpiration of applied water for NORMAL rainfall year (AF/acre/yr)[a]	Gross revenue per acre ($/acre/yr)[b]	Typical production & overhead costs ($/acre/yr)[c]	Annualized establishment costs (yrs. to full production)
Citrus, Subtropical, and Misc. Deciduous		2.71	$9,344	$7,428	$534 (6)
Pasture and Alfalfa		2.60	$1,603	$1,492	$206 (1)
Miscellaneous Truck Crops (Processed tomatoes)		2.08	$3,895	$3,781	N/A
Miscellaneous Field Crops (Corn silage)		2.06	$1,840	$1,634	N/A
Walnuts		2.76	$2,810	$3,568	$971 (8)
Grapes (Raisins)	40 acres	2.1	$4,221	$3,126	$900 (4)
Grain and Hay crops (Wheat)		1.17	$716	$ 765	N/A
Almonds	100 acres	2.83	$5,475	$ 3,301	$769 (6)
Pistachios		2.49	$4,650	$ 3,786	$609 (8)
Idle/Fallow	40 acres		--		--
Rangeland			--		--

a. Consumptive use is the amount of water transpired during plant growth plus what evaporates from the soil surface and foliage. The portion of water consumed in crop production depends on many factors, including irrigation technology. This table reflects the additional consumptive use demand above and beyond the consumptive use demand met by rainfall for the water year identified in Table 1.
b. Based on 2019 data from the Madera County Crop Report
c. Source: University of California Davis, Commodity Cost and Return Studies for San Joaquin Valley; does not account for fixed/capital expenses. These costs are intended to represent typical costs and have been updated to 2020 USD.

As the market administrator for the pilot, the consultant team facilitated trades based on a methodology being used in the groundwater market in developed by the Fox Canyon Groundwater Management Agency (located in Ventura County) for market exchanges (e.g., anonymous trading). As described previously, this method was selected based on input from stakeholders from Workshop 2. Administrators tracked simulated trades over the course of the pilot, allowing for monitoring of activity in areas of concern (i.e., groundwater withdrawals) and test the effectiveness of market rules. Each month, in addition to farm zone specific information, the County also provided a summary on trades and average water prices, and elicited feedback from participants.

Figure 5 provides a summary of the information provided to participants each month, as well as the information that participants provided each round.

County provided information to participants	Participant monthly responses
• Basic information on parcel/farm unit area, irrigated acreage by crop type • Groundwater allocation + carryover from previous round • Type of rainfall (wet, average, dry) • Consumptive use demand by crop type (changes based on rainfall type) • Amount of transitional water available to them in each simulated year and the cost of transitional water • Minimum economic information necessary for participants to make decisions with respect to market for each simulated year (e.g., average net returns over operating costs by crop type per acre) • Average sales price from previous year of trading • Information on available incentives or new rules, when applicable	• Decision to buy or sell groundwater allocations, if applicable, and associated "bid" • Amount of water they used that year • Irrigated acres by crop type, including changes made in response to reduced groundwater availability (e.g., fallowing or idling irrigated acreage) • Other management actions taken to reduce water demand/use • Feedback on market rules, process and factors that influenced their decision to participate/not participate in market in given year

Figure 5. Information provided to participants and participant responses for each month of the pilot

5.3 Market Structure and Rules

A key objective of the pilot project was to test the market structure and administrative processes, as well as the effect of market rules on growers' decisions to participate (or not) in the market. This section describes the general structure of the market (as developed for the pilot), as well as the different rules that were put in place over the course of the pilot. Some rules were established immediately, while others were crafted and implemented during the pilot based on participant feedback and need to mitigate unintended consequences.

As an important note, the County's adopted allocation policy was finalized after the pilot program was developed and initiated. As such, there are some key differences in the way that the simulated allocation approach was crafted for the pilot program. Specifically, sustainable yield allocations were held constant over the course of the pilot at 0.75 acre-feet per irrigated acre. Rangeland participants were assigned a sustainable yield allocation for their rangeland; however, they were not able to sell the sustainable yield allocations associated with the rangeland on the market (they could however, apply them for use on any irrigated acreage within their farm unit). Other variances between the market structure and the County GSA's allocation approach exist but are not relevant to the objective of this pilot market exercise.

5.3.1 General pilot market structure

Tradeable allocations. The units of trade in the market are sustainable yield allocations, which are bought and sold on a volume basis (acre-feet, AF). The pilot market was predicated on the sustainable yield allocation and farm unit approach that was being considered by the County GSA and ultimately adopted by the County GSA Board in December 2020, June 2021, and August 2021. Specifically, the pilot market program assumed the "opt-in" process for all landowners/farm units. It also assumed that individuals who "opt-in" declare their intent to pump groundwater and/or sell their sustainable yield allocation in any given year. Participants received their sustainable yield allocation each year, even if they chose to idle/fallow any of their irrigated acreage.

As noted above, for the purposes of the pilot program, participating ranchers were assigned sustainable yield allocations for their rangeland. However, sustainable yield allocations associated with rangeland were not eligible for sale on the market. Participants in the pilot could use the sustainable yield allocations associated with their rangeland on irrigated land that was part of their farm unit (for the pilot, all rangeland owners were assigned irrigated acreage in addition to their rangeland acres). These market structure rules were established to help test groundwater market concepts and functionality but were not mimicking the County GSA's detailed allocation approach that was subsequently adopted.

Transitional water purchases. Participants were offered the opportunity to buy transitional water (up to a set AF/acre quantity) at a cost of $200 per AF. As described previously, the quantity (AF/acre) of transitional water available to participants decreased over the course of the pilot, until no transition water was available in Rounds 8 and 9. The cost of transition water was established for the purposes of the pilot only. The amount that individuals will actually pay for transition water is pending an ongoing rate study being conducted by the County GSA.

Transitional water allocations could not be sold on the market.

Eligible participants. Eligible market participants include agricultural growers and farmers who would be eligible to receive a sustainable yield allocation for their irrigated acreage (or previously irrigated acreage), consistent with the County's allocation approach. Notably, the pilot included participants who did not meet these criteria; in these cases, participants were assigned hypothetical irrigated acreage and other characteristics so that they could participate in the pilot.

Non-eligible participants. While all pilot participants were assumed to meet the criteria for eligible participants, in an actual market, landowners who opt out of receiving a sustainable yield allocation would not be able to participate in the market nor would residential, commercial, or similar landowners.

Ranchers who do not have sustainable yield allocations associated with irrigated acreage (or previously irrigated acreage per the requirements above) also would not be eligible to participate.

Geographic location: The County GSA allowed all growers within the County to participate in the pilot program. However, as noted above, groundwater allocations are a prerequisite for a functioning groundwater market. Currently, the County GSA is the only GSA within Madera County that is using allocations as a method for complying with SGMA. In the future, other GSAs may opt to participate in a market; however, interested GSAs would need to establish allocations that are consistent with the sustainable yield identified in relevant GSPs.

Water purchase transfers. Buyers of sustainable yield allocations will pump more water where they are located, while sellers will forego pumping and using the sustainable yield allocations they sell. There is no physical transfer of groundwater allocations (e.g., a groundwater allocation is not pumped by the seller and conveyed to the buyer).

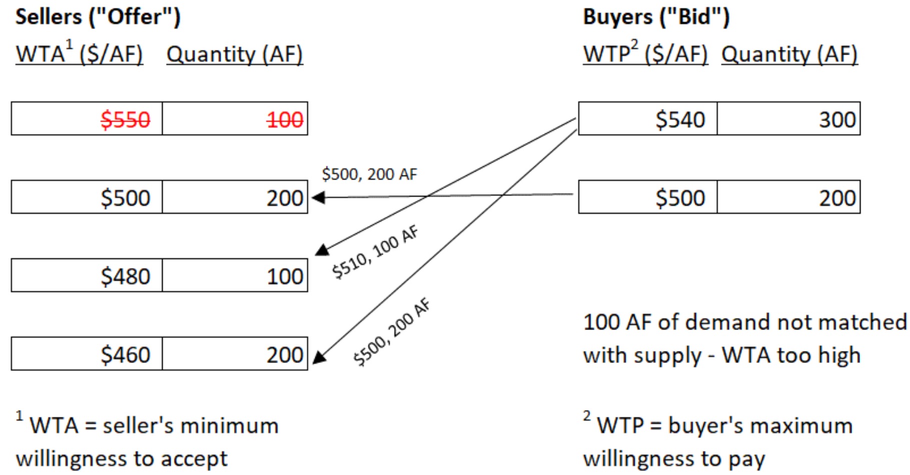
Matching buyers and sellers. Based on feedback received during previous workshops, market participants bought and sold groundwater allocations by submitting “bids” to the market administrator. Buyers and sellers were matched using a blind matching process to protect the anonymity and confidentiality of participants. Sellers were sorted in a spreadsheet according to their willingness to accept (WTA) when selling, and buyers according to their willingness to pay (WTP) when buying. First, the buyer with the highest WTP was matched with the seller with the lowest WTA. The price for this transaction is the midpoint between the WTP and the WTA.

With this process, multiple sellers (the ones with the lowest WTA remaining on the market) might be matched with a single buyer in order to provide the full amount requested by the buyer. If the first buyer’s request for water is fully satisfied and there is additional water available for sale in the market, then the buyer with the second highest WTP is considered, and the seller with the next lowest WTA is matched to that buyer. This matching process continues until all available water for sale is matched with a willing buyer as long as the seller’s WTA does not exceed the next buyer’s WTP.

The average price from a match between buyer and seller will always be lower than the WTP of the buyer and higher than the WTA of the seller from the match. The gains from trade are split evenly between the parties in the transaction. This approach provided anonymity and confidentiality of participants, removing the bias in trading so that all parties were neutral to one another. It also provides for more equitable access to the market across all participants. Figure 6 depicts the matching process.

Serving as the market administrator, the project team published information on total groundwater allocation sales and average price paid ($/AF) each month by subbasin. Names/parties associated with individual sales were not published.

Trading intervals. In an actual market, trades could be made at set intervals during the growing season and individual growers may have the opportunity to buy or sell allocations multiple times throughout the year, subject to the market rules. For the purposes of the pilot, participants made virtual trades once per month based on simulated information provided by the County GSA, which represented trading over a simulated year. During the stakeholder engagement process, some participants expressed a desire to buy or sell water much more frequently (e.g., on a weekly basis); however, as discussed in more detail below, given the expected limited supply of groundwater for sale, this may not be feasible.



Matching rules basics:

- Highest WTP is matched with lowest WTA.
- The price is the midpoint between WTA and WTP.
- Multiple sellers may be matched to a buyer and amounts for sale may be split between two buyers if needed to match amount demanded.

Note: Prices shown in diagram are hypothetical and do not reflect actual bids/offers from the market simulation.

Figure 6. Process for Matching Buyers and Sellers

Sustainable yield allocations can only be traded for use within a growing season or year (or within carryover limits, as discussed below). The market platform/administrator did not facilitate multi-year trades.

5.3.2 Market rules

Trading areas: Trading could only occur within each subbasin and was not allowed across subbasins or outside of the County. Trading was not restricted to specific trading zones, but in the last few rounds of the pilot program, trading rules were applied to buffer areas.

Purchasing transitional water: If a participant purchased transition water, they were not allowed to sell groundwater allocations on the market that round. This prevents purchasing affordable transition water and selling the water for a profit on the market.

Buffer areas: For the first seven rounds, no rules were applied to buffer areas. In Year 7, simulated dry conditions were assumed to result in a hypothetical decline in groundwater levels that had the potential to impact domestic wells and subsidence areas. Administrators therefore established an additional fee of $200/AF to groundwater allocation purchases that would result in additional pumping from within a buffer area. Revenues from the fee would be put towards recharge projects and/or to offset impacts to domestic wells or other sensitive areas.

Additionally, the County began offering an incentive to growers who fallow irrigated acres located within a buffer area. Specifically, if a participant idled acreage located in an identified buffer area, the County offered them $600 per idled acre. This incentive was offered every year from Round 6 onwards, renewable as long as the land continued to not be irrigated. This incentive was offered in addition to any proceeds received from selling the groundwater allocations associated with the fallowed acres (if the participant chose to sell them). The incentive applied to irrigated acres that were fallowed in previous rounds, as long as that acreage continued to be fallowed.

Carryover: At the start of the pilot, participants were allowed to carryover an amount of groundwater equivalent to 1-years' worth of their sustainable yield allocation into the next year. This means that a seller can sell up to two years' worth of the sustainable yield allocation in any given year. Buyers can carry over 1-years' worth of total allocations (including their own unused allocations and any water purchased, with the total not to exceed two years' worth of allocations). After month 5, the carryover limit was increased to 2 years' worth of total sustainable yield allocations based on participant feedback.

Resale of water: Once a buyer purchases water, it cannot be resold on the market that year.

Cap on purchases: For the purposes of the pilot, there was no limit on the amount of water per irrigated acre that a buyer could purchase. However, as noted above, there were limits to the amount of carryover that participants could save for use in the following year(s). During the pilot, the project team did evaluate whether water purchases would result in an exceedance of allowed carryover amounts for individual participants.

Penalties for overuse: Each month, participants reported their total irrigated acreage (by crop type), any deficit irrigation amount they applied, the amount of transition water they wanted to purchase, as well as the amount of water they would like to buy or sell on the market (if applicable). After accounting for these factors and completing market trades, the market administrator calculated the total consumptive use demand for each participant and compared it to the total groundwater available to them. If consumptive use exceeded groundwater supplies, the participant was assessed a penalty of $1,500 per AF of exceedance. Participants were given a 10% credit on overuse to account for measurement error. In a real-world setting, penalties would be assessed based on monitoring efforts conducted by the County.

The impacts of some of these rules are difficult to test, as in reality the consequences of trading could vary based on rainfall in wet and dry years, by well depth, and a variety of other factors. Rules based on the buffer areas or trading zones may also create inequities that do not benefit the groundwater basin. Throughout the pilot, the County obtained feedback from participants regarding the effect of different rules and parameters on their decisions.

5.4 Pilot Program Results and Key Findings

Over the course of the nine-month pilot, the project team tracked participant decisions and related outcomes to better understand the role of a potential groundwater market in meeting SGMA-related water use reductions. This section presents the results of the pilot effort, providing an overview of the following:

- Changes in irrigated acreage, farm unit management, and overall consumptive use
- Market trends, including supply, demand, and changes in the price of groundwater allocations
- Characteristics of buyers, sellers, and those who did not participate in the market

In addition to these measurable outcomes, this section summarizes participant feedback collected throughout the pilot, including overall impressions of (and need for) the market, reasons for buying and selling water (or not participating in the market), and the effects of incentives, fees, and market rules on their decisions.

As detailed in Figure 7, this section only describes results for participants who consistently participated in the pilot. The pilot results should not be interpreted as reflecting the exact outcomes of a potential future market (e.g., it was not intended to predict a future market price for water). However, the results and feedback received provide valuable indications of overall market trends and perceptions.

Figure 7. Participant Information for Pilot Market Analysis

A total of 58 stakeholders registered to participate in the market simulation. These 58 stakeholders were assigned to 62 farm units, with several participants being assigned crops in farm units located within two different farm unit zones. Crops were assigned to closely resemble participants' real life farming situation and to represent the actual crops grown in Madera County, proportionally. Additionally, the administrators made choices for five farm units. In total, the pilot included 67 farm units.

However, not every participant responded every round. In most rounds, the administrators chose three to five nonrespondent participants to idle land and sell the associated sustainable yield allocations on the market. These participants were chosen because they had not participated in previous rounds and their crop assignments included low-value crops, making fallowing and selling water a sensible economic choice.

Of the 67 farm units initially developed for the pilot, participants representing 34 farm units responded three times or more during the 9-round simulation. Of those, four were non-respondent participants for which the administrators made choices and five were county staff. In total, 25 official participant choices were analyzed.

All results presented in this report are based on the 34 farm units that participated regularly.

5.4.1 Changes in Irrigated Acreage and Associated Water Use

The consumptive use reductions necessary to meet sustainable yield in the Madera County GSAs will result in changes in irrigated acreage and the adoption of other farm management strategies. This was simulated in the pilot, as the sustainable yield and transitional water allocations available to growers only covered a portion of participants' consumptive use demand on a per-acre basis. For example, in a normal year, ETAW requirements for typical crops range from 1.17 AF per acre (hay and pasture) to 2.83 AF per acre (almonds). For the pilot, the sustainable yield allocation was set at 0.75 AF per irrigated acre, while transitional water allocations started at 1.75 AF per acre and decreased over time. These quantities were established for the purposes of the pilot but were intended to simulate a range of potential future conditions. In actuality, allocations will depend on various factors and will be re-evaluated by the County over time based on groundwater levels and the status/progress of projects implemented to increase water supplies.

Under a strict allocation approach, growers may opt to fallow land within their farm unit and use the associated groundwater allocations to continue irrigating the remaining acreage. Some may also opt to switch to lower water use crops and/or adopt other management strategies (e.g., deficit irrigation) to maximize the groundwater available to them. A groundwater market introduces additional flexibility by allowing growers to fallow land and sell the associated allocations on the market - this begins to make economic sense when an acre foot of water used to irrigate can be sold on the market for a higher price than the (per AF) profits earned from the crops that would use that acre foot of water. It also provides growers with the opportunity to purchase water on the market, thereby keeping more irrigated acreage in production on their farm unit than they would otherwise be able to.

Over the course of the pilot, participants adopted various strategies in response to decreased groundwater availability. In Round 1, pilot participants started out with 35,400 acres, 98% of which was cropped and irrigated (the remaining 2% represented fallowed, previously irrigated land). Over 10,000 of these acres were almond trees, representing nearly a third of all irrigated land (generally consistent with cropping patterns within the Madera County GSAs). Grapes were the next largest represented crop, with over 7,000 acres represented in the pilot, accounting for 20% of all irrigated acreage.

In total, participants idled 13,566 acres, leaving only 61% of the total original acres irrigated. The highest proportional fallowing occurred for crops of alfalfa/pasture, field crops and grains.[7] Nearly 2,700 acres of miscellaneous field crops, 2,300 acres of alfalfa/pasture, and 2,000 acres of grain were fallowed over the course of the simulation. These crops were fallowed almost immediately, with significant declines in acreage in the first two rounds of trading.[8]

Almonds and grapes also faced relatively significant declines in total acreage with just over 2,700 acres fallowed of each crop. Almonds and grapes are high value crops and were not fallowed in large quantities until the second half of the simulation when transition water became scarce. As discussed in more detail in the next section, some participants idled land for the purpose of being able to sell the associated groundwater allocations on the market; however, many participants who idled land used the "freed up" groundwater allocations to maintain other irrigated acreage within their farm unit.

Figure 8 shows the change in total acreage for each crop category from the beginning of Round 1 through the end of the pilot. The bold percentage indicates the proportional change in that crop over the duration. Overall, participant irrigated acreage decreased by 38%. In general, the results of the pilot were consistent with findings from the farm unit analysis described in Section 3in that "more likely to sell" crops were fallowed at a higher proportion. However, due to the nature of cropping patterns in Madera County (with a percentage of nut trees and other high value crops with relatively high consumptive use requirements), as expected, crops that fall within the "more likely to buy" category were also fallowed in response to reduced groundwater availability.

Participants took advantage of the lowest cost groundwater available to them. Transitional water was available from Round 1 through Round 7 but decreased over time from 1.75 AF/ per acre of irrigated or idled land until no transitional water was available by Round 8. As noted in the rules, participants who elected to sell water on the market were prohibited from purchasing transitional water during that round of trading. Participants who could purchase transition water purchased between 81% and 96% of the total available to them each round.

[7] Walnuts also saw a high proportion of crops fallowed, but the total walnut trees planted at the start of the pilot include <1% of all cropped acreage. The proportional loss is representative of a single farmer fallowing 60 acres of older walnut trees.

[8] As a note, these crops have been on the decline in general in the County GSAs (although grain and hay acreage in the Chowchilla subbasin have remined relatively stable over time).

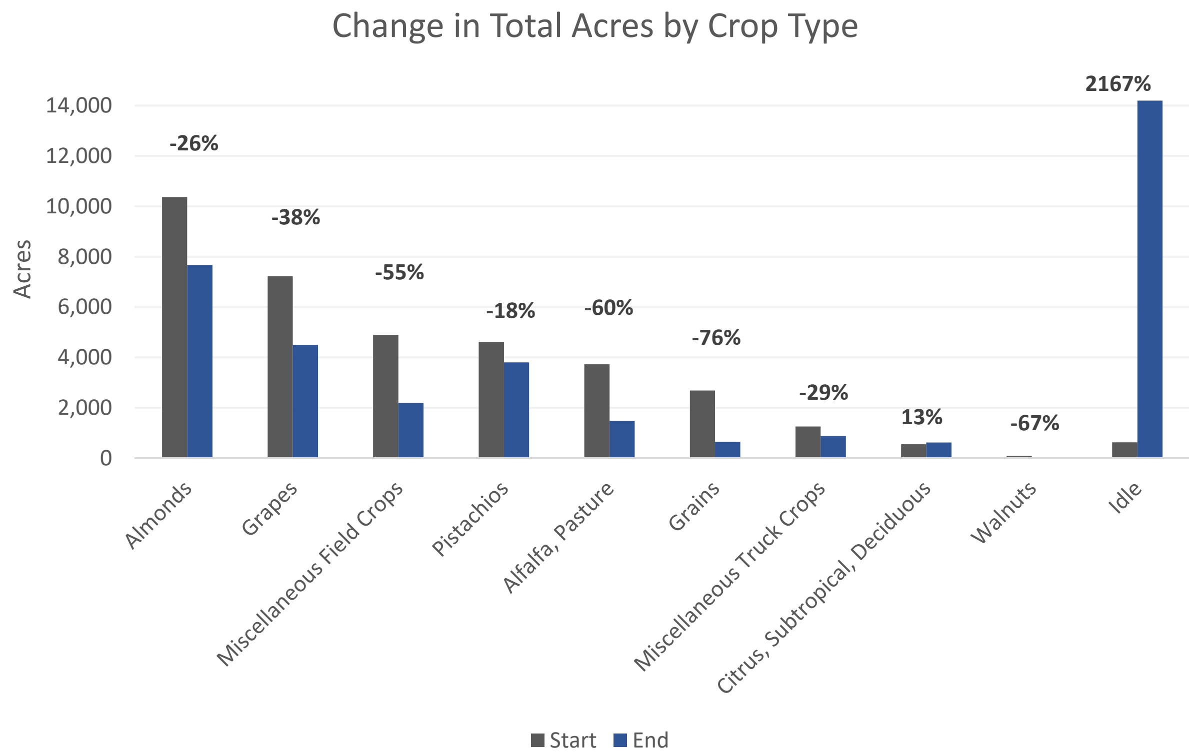


Figure 8. Change in total acreage by crop type from original assignments through the end of the pilot
Note: For Round 1 of the pilot, the project team assigned a total of 626 idled acres to participants. By the end of the pilot, idled acreage had increased to 14,192 – a 2,167% increase.

During the pilot, the project team also tracked nut tree ages over time, assuming (unless otherwise indicated by the participant) that fallowed nut tree acreage came from the oldest trees. Nut trees are of particular interest due to the lower water requirements of young nut trees (i.e., before they full reach full production) relative to older trees (which generally reach peak production between 15 and 20 years), as well as the prevalence of older nut trees in the County. The County was curious how farmers might respond to acres of aging trees in the face of water scarcity. Of the participants that were assigned almond crops in Round 1, more than half (6 out of 12) ripped up old almond trees and replanted new trees at some point during the pilot project. A total of 3,775 acres of new almond trees were replanted. One participant ripped out 80 acres of old almond trees and replanted new trees every round they participated. For pistachios, only one participant chose to plant new trees. This farmer chose to fallow 500 acres of old almond trees and move those trees into pistachios. No new walnut trees were planted during the pilot; one participant fallowed 60 acres of walnut trees in Round 2 and used the associated allocations to irrigate existing almond trees. Relatively few acres of walnuts are currently planted within the Madera County GSAs.

Replanting nut trees represents a short-term strategy for reducing consumptive use as trees will require their full ETAW after about 5 years, when less transition water will inevitably be available. However, replanting nut trees will extend the productive life of an orchard, perhaps biding time for additional recharge projects or new water supplies to come online.

Changes in irrigated acreage resulted in associated changes in the consumptive use of groundwater. It is difficult to compare year over year changes in the consumptive use of groundwater because the amount of rainfall (i.e., wet, dry, or normal year as simulated in the pilot) affects the ETAW requirements of crops. By the final round of the pilot, consumptive use was down 35% from the consumptive use associated with the initial crop allocations (under normal year conditions). Some of the largest decreases in consumptive use came in the first three rounds of trading, as participants decided to fallow less lucrative crops, as well as in later rounds when transition water was no longer available. Changes in consumptive use and overall irrigated acreage are summarized in Table 5.

Table 5. Consumptive Use and Transitional Water changes over duration of pilot program

Round[a]	Irrigated Acres			Consumptive Use			
	Total Acres	Year over year change	Change from R1	Water year type	Acre Feet	Year over year change	Change from R1
1	35,404	-13%	-13%	Normal	83,382	-	-
2	30,777	-13%	-13%	Normal	67,406	-19%	-19%
3	31,499	2%	-11%	Normal	69,485	3%	-17%
4	31,278	-1%	-12%	Dry	61,312	-12%	-26%
5	27,941	-11%	-21%	Dry	60,083	-2%	-28%
6	27,389	-2%	-23%	Dry	56,464	-6%	-32%
7	25,937	-5%	-27%	Wet	53,523	-5%	-36%
8	24,815	-4%	-30%	Normal	45,515	-15%	-45%
9	21,792	-12%	-38%	Dry	53,818	18%	-35%

a. irrigated acres and consumptive use reported reflects the numbers going into the respective round (i.e., based on conditions/decisions made in the previous round).

Participants provided information on other strategies they might use to decrease their consumptive use. Every round, between 4 and 6 participants indicated they would deficit irrigate their crops. Others suggested soil moisture monitoring, installing drip irrigation if they could afford it, rainfall capture infrastructure, and adding compost and bark chips around tree bases. However, as an important note, not all of these strategies reduce the consumptive use demand of crops – some only result in more efficient use of total groundwater extractions, likely having no significant net effect on groundwater levels.

5.4.2 Market Trends: Supply, Demand, and the Price of Water

In the first couple rounds of the pilot, the project team matched buyers and sellers regardless of which subbasin they were located in. While in reality this would not be allowed, a key objective of these initial rounds was to help participants become familiar with the market and pilot process, including the process for matching buyers and sellers. Thus, all participants were treated as though they were located within the same subbasin to maximize trading. In Round 3, the project team only matched participant buyers and sellers if they were located in the same subbasin.

Throughout the course of the pilot, participants with farm units located in the Chowchilla subbasin consistently had an excess supply of water while Madera subbasin had unmet demand. The price per acre foot of water was therefore lower every round in Chowchilla than in Madera. Tables 6 and 7 show total demand, supply, and market price by round, as well as excess supply and unmet demand, for the

Chowchilla and Madera subbasins, respectively. In some cases, unmatched supply was to due sellers requesting a price that was higher than any buyers were willing to pay. For example, in Round 3 of trading, two participants in Chowchilla were unable to sell their water due to an asking price that was too high for other farmers to purchase. In Madera, the supply was so low that the highest bidder bought all the water up for sale. The administrators of the pilot alleviated this mismatch in future rounds with additional non-respondent sellers.

Table 6. Trading results by round, Chowchilla subbasin

	R1[a]	R2	R3	R4	R5	R6	R7	R8	R9
Demand (AF)	8,005	4,265	611	1,001	1,102	1,557	636	986	1,609
Supply (AF)	1,227	1,119	620	920	2,438	2967	1,497.5	2,490	1,925
Total traded (AF)	1,227	1,119	20	920	1,102	1,557	539	986	1,609
Market price/AF	$574	$642	$891	$840	$940	$934	$991	$917	$863
% Demand met	15%	26.2%	3%	92%	100%	100%	85%	100%	100%
Excess supply	0	0	600[b]	0	1,336	1,410	958.5	1,504	316

a. For Rounds 1 and 2, results presented are for all participants (trades were not limited by subbasin)

b. In Round 3, two of three sellers in the Chowchilla subbasin priced their water higher than any buyers were willing to pay.

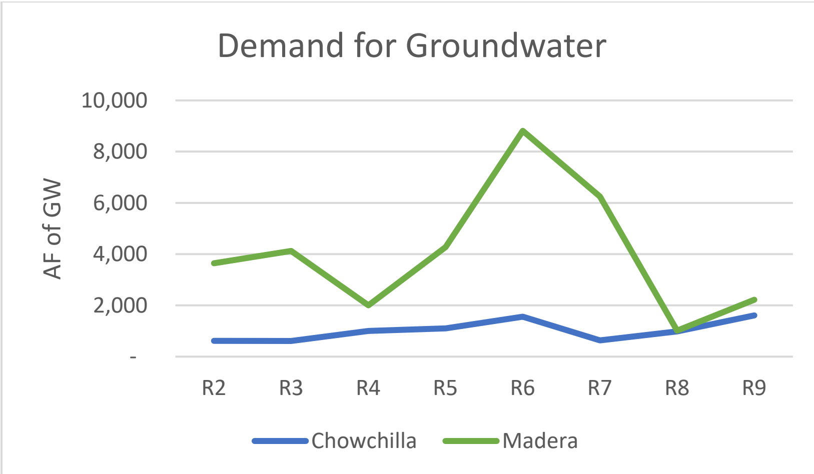
Table 7. Trading results by round, Madera subbasin

	R1	R2	R3	R4	R5	R6	R7	R8	R9
Demand (AF)	8,005	4,265	4,126	2,003	4,278	8,813	6,246	5,350	2,219
Supply (AF)	1,227	1,119	525	2,263	2,280	2,263	2,553	2,923	3,078
Total traded (AF)	1,227	1,119	385	2,000	2,280	2,263	2,553	2,923	2,219
Market price/AF	$574	$642	$905	$864	$ 982	$1,042	$1,038	$928	$858
% Demand met	15%	26.2%	9%	100%	53%	26%	41%	55%	100%
Excess supply	0	0	140	263	0	0	0	0	859

a. In Round 9 there were fewer participants than normal participating, particularly in the Madera subbasin, this is primarily why total demand is lower than the previous rounds, resulting in excess supply.

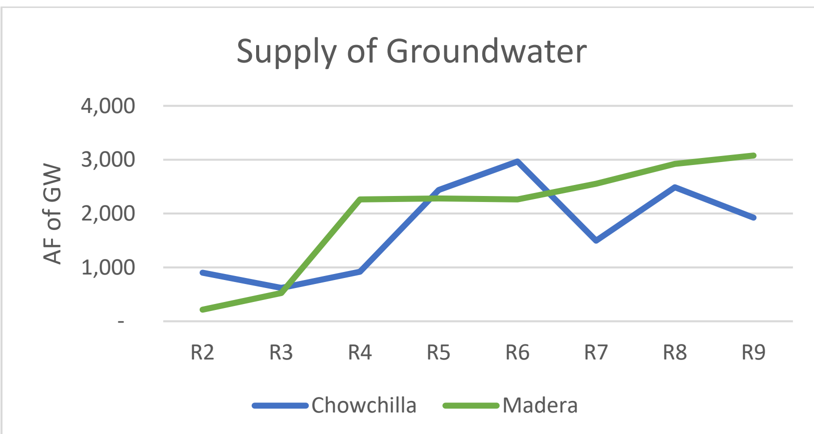
Figures 9 – 11 show demand, supply, and price per acre foot of groundwater over the course of the pilot. While specific results are in part a factor of who participated each round, the trendline for demand steadily increases until Round 6, after which there is a sharp decline. Rounds 4 – 6 were dry years, so the peak in demand may reflect increasing water scarcity (in addition to decreasing availability of transitional water). In addition, Round 7 was a wet year, which reduced the ETAW requirements for crops. The decline in demand after Round 6 may also reflect farmers' unwillingness to risk attempting to buy water on the market. Participants' comments reflect their aversion to the risk of basing cropping decisions on shifting market supply and price.

While supply also increases over time (Figure 10), the rate of increase does not keep pace with demand. In Madera subbasin, supply was often only 25% - 55% of total demand, while in Chowchilla, supply was regularly greater than demand.



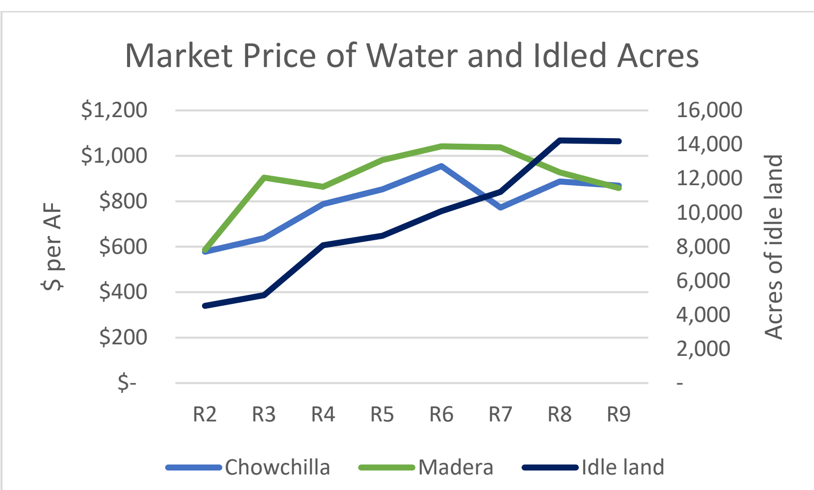
Demand peaked in Round 6 in the Madera subbasin, perhaps due to three years of drought, decreasing transitional water availability, and questions/uncertainty regarding market price and supply.

Figure 9. Demand for groundwater by subbasin and total over time



Supply in Chowchilla was consistently greater than demand in that subbasin. Although supplies are similar in quantity, there was typically excess demand in Madera.

Figure 10. Supply of groundwater by subbasin and total over time



Decisions about fallowing land in response to price would happen the year after a given price. The Rounds on the X axis indicate the price that round, and the idled acreage reflects the following round's decisions (i.e. R3 $/AF corresponds to total idled acres in R4).

Figure 11. Price per AF of groundwater and idled acreage by subbasin over time

Figure 11 shows that throughout the course of the pilot, the price of water on the market increased, as did the amount of acres fallowed. These trends outpaced the increase in demand, perhaps underscoring a reluctance to purchase water on the market.

Participants often commented about the high price of water on the market. To demonstrate this point, assume that a farmer must rely on market water to water some acres of his or her farm unit (see Table 5). The average price of water on the market from Rounds 4 - 9, ($971/AF in Madera and $851/AF in Chowchilla) was applied to the consumptive use per acre of each crop, after accounting for sustainable yield allocations of 0.75 AF/acre. As shown, the cost of water per acre exceeds accounts for a relatively high percentage of "typical" revenues for different crops (based on Madera County 2019 crop data). For low-value crops like pasture, alfalfa, grain and hay crops, the cost to purchase water exceeds the typical revenues from irrigated an acre of those crops.

Table 8. Per acre consumptive use, finance and cost of water statistics by crop type

Crop type	Consumptive Use: Normal Rainfall, after SY allocation applied	Revenue per acre (2019)	Cost to water 1 acre using water purchased on the market (% of revenues)	
			Madera	Chowchilla
Citrus, subtropical, deciduous	1.96	$9,344	$1,903 (20%)	$1,668 (18%)
Pasture, Alfalfa	1.85	$1,603	$1,796 (112%)	$1,574 (98%)
Misc. Truck Crops	1.33	$3,895	$1,291 (33%)	$1,132 (29%)
Misc. Field Crops	1.31	$1,840	$1,272 (69%)	$1,115 (61%)
Walnuts	1.45	$2,810	$1,408 (50%)	$1,234 (44%
Grapes	0.9	$4,221	$874 (21%)	$766 (18%)
Grain and hay	0.42	$716	$408 (57%)	$357 (50%)
Almonds	2.08	$5,475	$2,020 (37%)	$1,770 (32%)
Pistachios	1.74	$4,650	$1,690 (36%)	$1,481 (32%)

Source: Revenue data from the Madera County Annual Crop Report. Consumptive use data was derived from data from the GSPs.

Despite the high prices of water on the market, participants generally offered positive feedback about utilizing a groundwater allocation market as a tool to achieve groundwater sustainability. They recognized that the flexibility of the market helps manage the required decrease in groundwater pumping, with one participant calling the market a "necessary evil." Much of this support was caveated with concerns about how the market would be managed and wariness of larger investors or big farmers buying up all the water.

5.4.3 Buyers, Sellers and Non-Market Participants

As described in Section 4, It is suspected that growers who would be more likely to sell groundwater allocations (at least in the initial years of the market) primarily grow low-value crops such as grains, hay, pasture, alfalfa and other field crops. Those who are more likely to buy cultivate perennial, high value crops such as citrus and nuts. This economic reasoning held true in the market simulation, although with some important caveats.

Sellers: The largest amount of land idled over the course of the pilot happened immediately after Round 1, where nearly 4,600 acres of irrigated land was fallowed. Nearly half of the fallowed acres that round came from sellers fallowing pasture, alfalfa, and field crops. While grain crops were also fallowed to sell water over the course of the pilot, those crops did not see the same decline in acreage as pasture, alfalfa, and other miscellaneous field crops. Between 7 and 11 participants sold water each round and they mostly remained consistent as sellers.

Very few responders offered insights into their decisions to sell water on the market. One participant sold their allocations associated with a farm unit in the Chowchilla subbasin (where they grew wheat) in order to finance the purchase of water for tree crops on their farm unit in Madera subbasin. Participants were asked if there was a guaranteed price at which they would sell their allocations instead of watering crops. Responses ranged between $600 and $3,000 per AF, with one participant consistently concluding that they would not sell water without a long-term commitment from the purchaser.

Some respondents indicated they would sell water when it became more profitable than the crops they grow. However, this was not necessarily reflected in participant decisions as many individuals chose not to sell water even though it would likely be in their economic interest to do so. In comparing the revenues from Table 5 (above) to the "typical" operating and overhead costs for different crop types (based on local crop budgets published by UC Davis), the expected profits from selling water exceed or come close to the typical profits that growers in the area receive from most crops, with the exception of almonds, citrus trees, and grapes. This is based on average data; the economics of individual farm units vary based on several different factors.

Buyers: Participants who attempted to buy water on the market grew citrus/subtropical/deciduous, nut trees, and grapes. Every round between 6 and 12 participants attempted to buy water. Successful buyers offered a very high willingness to pay for water and often bought, or tried to buy, large quantities (>1,000 AF). In the first several rounds, participants reported only buying water to keep as carryover for the following years. By Round 6, buyers in Madera reported that they wanted to buy water due to lack of transition water and expressed frustration with the risk of relying on market water to irrigate their crops. However, as one buyer in Chowchilla pointed out during Round 7, there "always seems to be enough" supply in their subbasin.

> *Not interested in relying on the market for water anymore. The pilot was very useful in pointing us in that direction after several rounds. Just too risky! – Buyer turned non-market participant, Round 9*

Non-Market Participants: Participants who chose not to buy or sell water (non-market participants) mostly grew high value crops. In Round 4 there were 14 non-market participants. In the final rounds of trading, those numbers dwindled to 6 and then 3. This reflects the hard choices farmers had to make as water became scarce. Early in the pilot, many reported that they were able to survive by buying their maximum amount of transition water or fallowing a portion of land to continue to water their other crops. Without transition water, and with variable market supply of water to purchase, participants decided to either try to buy water on the market or fallow more land and sell.

> *"I'm assigned permanent crops in the simulation (and real life as well) …at what point do you want to rip out the permanent crop, get out of farming, and exploit the property's SY market value. Difficult decision to make for a permanent crop grower. At this point, my objective in the simulation is to keep farming as long as possible."*
> *– Small grape farmer who had idled half his land, Round 4*

In many cases, participant decisions demonstrated an attachment to farming that supersedes the economic value of selling water on the market. As early as Round 1, participants responses indicate they would rather fallow land (or in some cases, specifically older nut trees) and continue to farm (i.e., use the allocations to continue irrigating other acreage within their farm unit) rather than fallow the land to sell the associated allocations on the market. Even when transition water was no longer available, participants reported that their goal was "to maintain as much irrigated acreage as possible." In Rounds 4-7, participants were asked how groundwater availability would affect their decision to buy or sell water: fallowing more land consistently outranked buying more water on the market every round. Occasionally participants commented they would crop shift from current crops to higher yield nut crops, which was not an uncommon occurrence.

This trend of farming at all costs reflects the specific preferences of the farmers in this region at this time. These preferences might not always prevail. In the future, as the lower available groundwater supply stabilizes, farmers in the next generation might have a change in attitudes.

5.4.4 Incentives, Fees, and Rules

Throughout the course of the pilot, the project team evaluated the effect and/or role of different potential market rules. This section describes these rules and summarizes feedback from participants on how these regulations affected their decision-making process.

$1,500/AF Penalty: Implemented from the start of the program, the County assessed a $1,500 penalty for every acre foot of consumptive use that exceed the groundwater available for the participant by more than 10%. The penalty essentially serves as a price ceiling for what farmers would be willing to pay for water on the market (i.e., rather than pay a higher price on the market, they could simply pay the penalty). Occasionally participants would report drastic deficit irrigation, presumably to avoid paying the penalty. Most participants managed their farm unit to avoid penalties throughout the course of the pilot. At the outset of the pilot, the County considered a lower penalty amount; however, stakeholders suggested a higher price for the penalty to ensure compliance, indicating that many growers would be willing to pay a lower amount (e.g., $500 to $1,000 per AF).

Allowable Carryover: In Round 5, allowable carryover from year to year was increased from 1 years' worth of sustainable yield allocation (i.e., 0.75 AF/acre could be carried over for use or sold in the next year) to 2 years' worth of sustainable yield. One third of responders indicated that the increase in carryover helped with planning and security, as well as possible financing for water sales in the next round. The majority, though, reported that there generally is not enough water to carry over from year to year to meet this threshold. Very few participants ever met the carryover threshold once it was increased.

Incentive for Idle Land: Starting in Round 7, participants were offered an incentive of $600 per acre for land fallowed in an identified buffer area. The incentive was offered every year as long as the land continued to not be irrigated. In each round that this incentive was offered, the majority of responders suggested that the incentive program did not influence their decision to fallow land and sell sustainable yield allocations on the market. These folks suggested that they wished to keep farming and use their water on their own land; they would not sell water even if they fallowed the land and received an incentive. The participants that were influenced by the incentive reported that it was more profitable to be paid not to farm. The incentive was large enough to not have to rely on selling water on the market and still be able to make a profit. By the end of the simulation, 22 of 34 participants idled land in the buffer areas and were eligible for an incentive. This idled land only constituted a third of all land in buffer areas. The results are summarized in Table 9.

Fee for Purchasing Water to Irrigate in Buffer Areas: In Round 7, an additional fee of $200/AF was applied to the purchase of water on the market that would be utilized to irrigate in a buffer area. Fees were calculated based on the shortage of water needed to irrigate crops in the buffer area that was purchased on the market (instead of all water that was purchased on the market).[9] One third of participants reported that this influenced their decision to fallow the land in their buffer area, as they could no longer afford to buy water to continue irrigating. The remaining responses indicated that the fee was not a concern or did not understand the question. Only 6 participants in Round 8 and 5 participants in Round 9 incurred a fee for the purchase of their water on the market.

Table 9. Aggregated results for incentive for idled land in buffer area and fee for purchasing water to irrigate in buffer areas

Round	Incentive for Idle Land in Buffer Area				Fee for BA Irrigation	
	# of participants	Buffer area acres idled	% Idled of Total Buffer Areas	Total incentive payout	# of participants	Total fees paid
Round 7	18	2,469	18%	$1,481,422	--	--
Round 8	22	4,375	32%	$2,624,760	6	$465,165
Round 9	22	4,375	32%	$2,625,000	5	$218,169

Timing of trades. Over the pilot, participants had the opportunity to make virtual trades once per round, which represented trading over a simulated year. During the stakeholder engagement process, some participants expressed a desire to buy or sell water much more frequently (e.g., on a weekly basis); given the expected limited supply of groundwater for sale, this may not be feasible as it would likely exacerbate the mismatch of supply and demand. However, a market could easily be structured to implement multi-trading opportunities within a growing season (which could depend on trading activity). This would also provide an opportunity for sellers who may have priced their allocations too high to revisit their asking price.

Over the course of the pilot, several participants also commented on the need for multi-year or long-term trades. This could be facilitated through the market administrator and would need to be monitored for any potential unintended consequences.

Locational restrictions. Due to the limited number of participants, the project team was not able to test the effect of limiting trading to farm unit zones or to within (or across) identified buffer areas, or other directional/locational restrictions. The farm unit analysis described in Section 4 indicates that while crops that are likely to have more demand for water are relatively evenly distributed across farm unit zones, crops that are more likely to sell are more concentrated in some areas. This has the potential of limiting trading activity in areas that are anticipated to have less supply of groundwater allocations on the market.

[9] The fee for buying water on the market to irrigate buffer areas was calculated by determining the sustainable yield + carry over available to water crops. Within the buffer area, if the consumptive use for crops was greater than the available water, the fee was applied to the amount of water purchased on the market that would be necessary cover the exceedance. It was possible to buy water on the market but not have a shortage in the buffer area and therefore not be assessed a fee on their purchases.

6. Conclusions, Lessons Learned, and Recommendations

Stakeholders, participants, and County officials expended significant efforts to undertake a pilot groundwater market trading program. The feedback from workshops, results from monthly rounds of trading, participant feedback and implications of different market elements offer insights into the value of a market-based solution for managing groundwater demand in the Madera and Chowchilla subbasins. This section summarizes lessons learned and makes some recommendations for the County to consider moving forward.

6.1 Conclusions and lessons learned

Several key themes emerged from the implementation of the pilot:

- Particularly in early rounds, many participants opted to not participate in the market (i.e., buy or sell groundwater), preferring to deficit irrigate, and/or fallow land and use the associated allocations to irrigate other acreage within their farm unit. Market activity/interest picked up over the course of the pilot as the availability of transitional water decreased.
- Many participants were reluctant to try to buy water on the market due to uncertainty related to available supply and the price per acre-foot of groundwater on the market. As described in Section 5, in the Madera subbasin, there was often not a sufficient amount of supply to meet the demand for purchasing groundwater allocations; this likely resulted in a higher price for water and provided additional uncertainty as to whether a potential buyer would be able to purchase water on the market.
- Several respondents indicated they would sell water when it became more profitable than continuing to grow crops. Based on participant comments, it is likely that additional supply would begin to be available on the market over time. However, if a market is implemented, trading activity would likely be relatively limited in the early years.
- Some participants made decisions to help buy them time while the County or others develop new water supplies and expressed optimism that this would occur (e.g., several ripped out old trees and planting new ones, fallowing land with the option for returning them to production).
- High-value, permanent crops make up a large percentage of total irrigated acreage in the County GSAs; as expected, this meant that some of these lands were fallowed over the course of the pilot. This also makes it difficult to predict where purchases will come from (i.e., where additional pumping will occur) because growers with the same crops will make different decisions based on their individual circumstances and preferences (i.e., some almond growers may try to buy water while others will not, still some may even sell water). There is some evidence that incentives could be used to encourage individuals located in buffer areas to fallow and sell their groundwater allocations. In this way, a market could reduce potentially adverse effects on the groundwater basin.
- The high price of water could pose a greater challenge for small farmers, but this will depend on individual circumstances. Compared to a strict allocation approach, many farmers may be better off financially because they are able to sell allocations.

- Many participants provided positive feedback with respect to the pilot, indicating it was a valuable exercise. Several participants also provided comments indicating wariness or mistrust of the County/state and motivations behind SGMA.

- Although some expressed concerns, participants were generally supportive of the market as a useful tool to provide flexibility on the path to sustainability, with caveats regarding management and concern for their future as farmers. This positivity regarding the market is especially poignant given that many farmers saw the "writing on the wall," as one participant put it, and were not hopeful about their future in profitable farming. Overall, a market does seem to provide more flexibility in allowing farmers to make choices about their water usage.

> *"I am learning a lot from the pilot process and would very much like to see it implemented during the upcoming years in SGMA"*
>
> *"Great game!!! Especially if it's BOTH sides that are learning they're going to have to change and be more flexible. . . "*
>
> *-Round 4 participants*

- Trading was done using an algorithm that matched the highest bidder with the lowest willingness to accept and averaging the price of water between the two to complete the sale. The method of "nearest neighbors" was also tested every round, matching the highest bidder to the highest willingness to accept. There was very little variation between the outcomes of these two methodologies in terms of market price. However, there was often water left unsold on the market because sellers asking price exceeded any buyers' willingness to pay. This inefficiency might not be desirable given the water scarcity that so many farmers will be facing in the coming years, although it would likely be minimized over time as the market price begins to stabilize.

- Given the small sample size, conflicting feedback from participants and few rounds in which transition water was unavailable, it is difficult to determine the effect of incentives or fees on participant behavior; generally, the incentive program received positive feedback.

- Farmers lead very full and busy lives. This project could not have happened without the participants that volunteered their time to respond consistently. However, participants often needed multiple nudges and extensions of deadlines to submit their responses.

- Finally, the groundwater pilot market was time consuming to administer; it required tracking participant decisions/data, predicting consumptive use, reporting individual results, in addition to matching buyers and sellers. An actual market would not require the same level of data collection and much of the necessary data would likely be tracked as part of the groundwater allocation tracking and monitoring. Conceivably, administrative processes could be streamlined into the overall process for the GSAs.

6.2 Recommendations

The purpose of the pilot was not necessarily to definitively determine whether the County should implement a groundwater market. Initial results indicate that it could be a useful tool for meeting SGMA requirements but that there are some challenges. If the County moves forward with a market, there are several key things to consider for implementation. The following recommendations are derived from the experience of administering the pilot market and the feedback received along the way from County officials and participants alike.

Thank you for letting me participate and putting together a very interesting and enlightening program! I really wish I could have run several farms in order to see if my operation would have fared better with different decisions over the course of the game. I do not like the buffer zones… all of the drinking wells in our area are at depths below the ag wells, our groundwater levels have been steady for decades and the shallow ag wells we have do not cause subsidence. But…our farm that has been around for nearly 80 years will likely get swept up in a "buffer zone" because of [our neighbors'] farm practices. It is not sustainable for them to drill 80+ new deep wells in the last dozen years and convert 12,000 of permanent pasture to trees when the natural resources out here cannot support it. – Small farmer growing almonds in a buffer area, Round 9

Hire a neutral third party to administer trading and enforce rules or assess penalties. Many stakeholders expressed distrust of government officials and their capacity to neutrally administer a groundwater market. This could be alleviated in part by allowing a third party to administer the market, and to keep key information confidential.

Keep the matching process simple. Initial stakeholder engagement indicated a preference for confidentiality and anonymity related to groundwater market trades. For the pilot, the project team adopted the smart market method adopted by Fox Canyon Groundwater Management Agency in Ventura County (as described in Section 5). While this approach worked well and is economically efficient, it did introduce uncertainty as to whether a buyer would receive the full amount of water they wanted to purchase (although this is not necessarily unique to this approach). Publishing results regarding the cost and magnitude of trades after each trading period should reduce uncertainty to some extent. Other markets have also successfully employed more traditional approaches, whereby willing sellers and buyers bid through a more open forum rather than matched by the market administrator based on WTP and WTA. This type of trading was suggested by a participant in the final round of comments, but this approach does not offer obvious additional benefits. The matching algorithm used in the pilot can be administered using a simple spreadsheet.

Financial transparency for funds generated from the groundwater market. For similar reasons as above, provide as much transparency as possible with the fees and fines that are collected on behalf of Madera County. If these funds are used to finance projects that increase groundwater recharge or increase flood flow capture, publicize this information widely.

Only implement rules when it is absolutely clear that a rule needs to be put in place. As noted earlier, it is difficult to predict where a groundwater market might result in increased groundwater pumping (i.e., where purchasers will be located). This is due in part to the high percentage (and relatively even distribution) of crops that are "more likely to buy" groundwater. The farm unit analysis described in Section 4 does provide some insights as to where supply (and in some cases demand) might be more concentrated. Given the inability to predict specific impacts or trades, it does not make sense for the County to put restrictions in place that would limit trading to particular buffer areas or zones (perhaps with the exception of farm unit zones, addressed below). It would be important for the County to monitor sales, and the effects of other SGMA-related management actions, and to proactively manage the program consistent with thresholds and objectives outlined in the GSPs**.** This is consistent with lessons learned from other markets, where the consequences and benefits of market rules were not fully understood.

Rules such as limiting carryover and penalties for overuse would play a key role in the market and should be implemented at the outset. The amount of allowable carryover could be revisited over time.

Rules for matching buyers and sellers could also be adapted over time. For example, sales could be capped to a set amount per irrigated acre as a way to allow more people access to available supply. A certain proportion of available supply could also be designated for small farmers to ensure equitable access.

Limit trades to farm unit zones. The County GSA's allocation approach limits the use of groundwater allocations to lands collectively operated within the same farm unit zone. This leads to a default assumption that trades would also likely only be able to occur within the same farm unit. However, this has the effect of limiting market activity/flexibility, particularly because obvious sources of supply are somewhat concentrated in specific farm unit zones. The County may consider allowing trades across farm unit zones subject to review and careful consideration of net benefits and impacts. This would likely need to be integrated into the allocation approach, such that it would also allow farmers who collectively manage irrigated acres across zones to manage that water flexibility (subject to review and potentially fees).

Incentivize strategies to reduce consumption and generate supply. Participants made very thoughtful suggestions throughout the pilot on how to conserve water. If there is a means to support a program that would incentivize recharge projects that could generate allocations for sale on the market or land conservation (as is being considered by the County), particularly in areas where it is most needed, those avenues should be explored in tandem with the market. The County could also explore a purchase guarantee program whereby unsold allocations would be purchased by the County at a price slightly lower than the market price. This provides additional certainty to sellers that allocations will be sold, which could help to ensure additional supply.