To be used for intro section.

# Groundwater Demand Management Conceptual Contents



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SUSTAINABLE GROUNDWATER MANAGEMENT (SGM) GRANT PROGRAM

## OVERVIEW [MM-13 to MM-14]

# Groundwater Demand Management Conceptual Monitoring Methods - Overview

| | |
|---|---|
| **Project / Management Action Type** | Water Demand Management includes overarching projects, actions, or policies that an agency can put into place to reduce net use of groundwater within an area or groundwater basin. |
| **Similar / Related Project Types** | Demand management is implemented in coordination with all other GSP projects and management actions. |
| **Metric** | Net water use or depletion (extraction less recharge of that extraction).<br>Groundwater levels.<br>Applicable water quality constituents (situationally). |
| **Measurement Unit** | Consumptive use plus other losses to the groundwater basin. |
| **Beneficial User** | Municipal and domestic water supply (MUN)<br>Industrial service supply (IND)<br>Industrial process supply (PROC)<br>Agricultural water supply (AGR)<br>Freshwater replenishment to surface waters (FRSH) |

## Introduction

Water managers have two main options to achieve sustainable groundwater management in California: 1) augmenting water supply and 2) reducing water demand. Many Groundwater Sustainability Agencies (GSAs) strive for **water supply augmentation** in their Groundwater Sustainability Plans (GSPs) because it is viewed as maintaining the basins' economic and growth activities. Water supply augmentation projects bring additional water into a basin, such as surface water transfers, flood capture [MM-03] and recharge [MM-04], rainwater harvesting, and recycled water use. For the purposes of sustainable groundwater management, supply augmentation projects must bring new water into the basin or keep water within the basin that would have otherwise left the basin.

Increasing droughts and pressure on already constrained water resources mean that water supply augmentation alone may not be available or enough to achieve sustainability in every basin. There may not be enough water available for the combined supply augmentation projects described in the submitted GSPs (PPIC, 2020 and 2021). In addition, the cost of water supply augmentation projects increases with the total volume of new supply. It can be more cost effective to include demand management projects that reduce water use instead of, or in addition to water supply augmentation.

Demand management broadly refers to any water management activity that reduces the total use of water. For groundwater sustainability, demand management must result in a reduction in net groundwater pumping (pumping net of recharge), or alternatively, net depletion. In this context, activities such as reducing canal seepage or deep percolation from irrigation would not be effective; they may decrease the quantity of water diverted or applied but also reduce recharge to usable groundwater, and so do not reduce net depletion from the aquifer.

Demand management should be developed in coordination with other projects (such as groundwater recharge [MM-01 to MM-06]), to help with the overall balance of water use and demand to reach sustainability.

**KEY TERMS**

**Water supply augmentation** includes projects that bring in additional water supplies or capture water that would have otherwise left the basin, such as floodwater capture and recycled water use.

**Groundwater allocation** is an amount of groundwater use that has been defined and quantified over a period, usually one year, and can be assigned or distributed to specific users within a basin.

## Groundwater Demand Management Categories

A demand management program could potentially provide a benefit to all sustainability indicators in a subbasin and –in combination with other projects and management actions—be a solution to reach groundwater sustainability. General types of demand management programs include:

- **Groundwater Allocation**: Under an allocation, a share of total available annual supply of groundwater is allocated to individual parcels, wells, or entities (such as, for example, farming operations). An allocation is a rigid method for implementing demand management and limits water use at a well, parcel, or on an operation basis. Defining the quantities of groundwater available to individuals can incentivize demand management and the development of alternative water resources or a change in water use.

  For the program can be implemented effectively, allocations must measure the water used with each user's allocation. Normally, metering is associated with each allocation. However, metering can be expensive, and is a measure of gross, not net, water use. It is possible to calculate gross or net water use based on crop type and reference evaporation, or to calculate water pumped based on pump energy use, pump efficiency and pumping head which includes depth to water and irrigation system pressure. Remote sensing methods can also be used to calculate gross and net water use.
- **Groundwater Allocation Combined with Trading**: Allocations can be coupled with water trading, or a "water market." A groundwater trading program is way to reduce costs of allocations by allowing willing buyers to pump more than their allocation by paying sellers to pump less of their allocation. Trading through markets affords groundwater users more flexibility in how they use their allocation, which reduces the total economic cost of allocations. Refer to MM-14 for a complete discussion of groundwater trading programs.

– **Land Use Changes or Repurposing**: Land use changes in agricultural settings can be implemented by replacing current crops with less water intensive crops, also coupled with changes in irrigation technology to reduce net water use. Land repurposing programs refer to the conversion of currently irrigated lands into other, non-irrigated uses. In land fallowing (or idling), as opposed to land retirement, the land is not irrigated but the capability to irrigate in the future is maintained. Land repurposing is more targeted than groundwater allocations and trading. It allows demand reduction to focus on the least productive land or on land that is valuable for some other purpose such as habitat.
– **Urban Demand Reduction**: In urban settings, stakeholder outreach and education programs (including conservation messaging, technical support, and pricing mechanisms), implementation of efficient appliances, and agency water loss reductions, can help with water demand reduction.
– **Financial incentives**: Demand management can also be achieved through a range of financial incentives from changing practices such as land use or rebate programs.

For the purpose of these Monitoring Methods, groundwater demand management should be limited to the projects or management actions that would directly relate to groundwater sustainability. The general categories of demand management programs described above all work to reduce demand. Therefore, **demand reduction [MM-13]** is described under its own section below. Demand reduction includes a range of projects or management actions that aim to reduce the net amount of groundwater use. Demand reduction for groundwater sustainability purposes must reduce net depletion. These programs can be urban-based or agricultural-based.

Groundwater allocation and trading would enable willing buyers and sellers of water to exchange groundwater within a subbasin. Groundwater allocations can help control demand in a basin, while trading is an institution that can help shift water use and pumping from one area to another, while reducing overall cost of demand management programs. Therefore, **groundwater trading** is described separately as **MM-14**.

## Sustainability Indicators

The Groundwater Management Conceptual Monitoring Methods will be applied to projects or actions that include demand reduction or incorporate groundwater trading. The applicability of these projects or actions to the six sustainability indicators as defined in the Sustainable Groundwater Management Act (SGMA) is presented in Table MM13/MM14-1.

**Table MM13/14-1. Groundwater Demand Management Conceptual Monitoring Methods Levels of Benefit to the Six Sustainability Indicators Outlined in SGMA.**

| Six Sustainability Indicators Outlined in SGMA | Demand Reduction | Groundwater Trading |
|---|---|---|
| Depleted Interconnected Surface Water | ★ | ★★ |
| Lowered Groundwater Levels | ★★★ | ★★★ |
| Water Quality Degradation | ★ | ★ |
| Subsidence | ★ | ★★ |
| Reduced Groundwater Storage | ★★ | ★★★ |
| Seawater Intrusion | ★ | ★ |

*Notes
★★★ = Primary Benefit (High Applicability)
★★ = Secondary Benefit (Medium Applicability)
★ = Situational Benefit (Applicability dependent on Location, Site Characteristics, and Aquifer Condition)

# Demand Reduction Monitoring Method - Overview
# MONITORING METHOD [MM-13]

SUSTAINABLE GROUNDWATER MANAGEMENT (SGM) GRANT PROGRAM

## MONITORING METHOD [MM-13]

# Demand Reduction Monitoring Method

| | |
|---|---|
| **Project / Action Type** | Water Demand Reduction encompasses a range of projects or actions, including allocation and measurement, land repurposing (irrigated land fallowing), water use efficiency (efficient irrigation that reduces net water use); change in crop mix, reducing real losses in the delivery system (e.g., by infrastructure upgrades); customer water conservation and water-efficiency measures such as water-efficient appliances, drought tolerant landscape programs, and behaviour-based measures (including water pricing, conservation messaging, norms-based messaging etc.). |
| **Similar / Related Project Types** | Other demand management projects. |
| **Metrics** | Net water savings or reduced net depletion (extractions less recharge).<br>Groundwater levels.<br>Groundwater quality. |
| **Measurement Units** | Water demand reduction measured in acre-feet and measured as reduced consumptive use plus reduction in other losses to the basin.<br>Groundwater levels measured in feet in a consistent vertical datum.<br>Concentration of applicable constituent of concern. |
| **Beneficial Users** | Municipal and domestic water supply (MUN)<br>Industrial service supply (IND)<br>Industrial process supply (PROC)<br>Agricultural water supply (AGR) |

## Demand Reduction Overview

**Demand reduction** or Demand Management Measures (as named in the Department of Water Resources' [DWR's] *Urban Water Management Plan Guidebook*, 2020) broadly refers to any water management activity that reduces the use of water. To be effective for purposes of sustainable groundwater management, demand reduction must result in a decline in net groundwater depletions. That is, it must reduce consumptive use or other losses to the basin, or otherwise reduce net water use.

Demand reduction programs can include reducing net water use via water efficiency (through applied technology) and water conservation measures (through behavioral change). Demand reduction can be achieved through various projects or management actions targeting agricultural, urban, or industrial water uses.

- Urban demand reduction can include stakeholder outreach and education programs (including conservation messaging, technical support, and pricing mechanisms), implementation of efficient appliances (sometimes aided by rebate incentive programs) and reducing delivery system losses. Additional recycling is demand reduction where wastewater was leaving the basin, not being reused or recharged. Some demand reduction programs reduce the amount of water delivered but have little or no effect on consumptive use. Indeed, they could reduce water reuse (recycling) by the same amount of reduced water delivery.
- For industrial water, water demand reduction often refers to use of a different technology or additional treatment and reuse of the available water supply.
- For agriculture, demand reduction can include changing to less water intensive crops and **fallowing fields**. Efficient irrigation and on-farm water management are sometimes included as potential demand reduction programs. However, more efficient irrigation such as drip can lead to an increase in crop evapotranspiration of applied water and thereby increasing water demand. The irrigation practice that maximizes applied irrigation water efficiency may not minimize net water use[1]. Reduced pumping from irrigation conservation practices may not reduce net use of water because the consumptive use requirement of the crop is unaffected. Also, more efficient irrigation practices may lead to less percolation to groundwater.

Demand reduction measurement and tracking requires detailed water balance calculations for each water use practice and conservation method that show how much extraction is changed and, without the conservation, the fate of the water that is no longer being extracted. Such calculations are required to monitor and assess the benefits of individual demand reduction practices. Where the fate of applied water is consumptive use and recharge only, reduced consumptive use is a good measure of net water savings.

## Monitoring Objectives

An important requirement of a Demand Reduction Monitoring Method is to track and measure the net groundwater savings (or reduced net depletion) attributable to individual practices and the entire program. Monitoring should be used to assess benefits to the aquifer that ultimately achieve sustainable management objectives for the basin.

This Demand Reduction Monitoring Method provides general guidance on assessing the effects of demand reduction on aquifer conditions and groundwater sustainability goals. Demand reduction measures can have complicated hydrologic effects that may require complex and careful monitoring. It is important to identify net ("real") water savings as reductions in consumptive use or irrecoverable losses. Generally, only a

**KEY TERMS**

**Demand reduction** management actions can reduce water use through water efficiency and water conservation measures.

**Fallowed fields/land** are agricultural lands that are maintained in good agricultural and environmental conditions but will not be planted and harvested for the duration of a crop year.

[1] For example, a sprinkler system could have a 70 percent applied water efficiency with most of the remaining 30 percent evaporated by spray drift. Furrow irrigation could have a 60 percent applied water efficiency with most of the remaining 40 percent percolating back to groundwater.

portion of an applied water reduction is a real water savings. Changes in percolation back to the aquifer, or to other water bodies such as streams or adjacent basins must also be tracked. Quantifying the amount of water saved requires developing a consistent baseline condition that describes what water use and the fate of water would have been in the absence of the demand reduction program. This would be coupled with a careful water budget that accounts for the amount and timing of return flows, the fate of return flows and percolation to groundwater, and evaporative losses.

Table MM13-1 below identifies the relative level of benefit of demand reduction for the six sustainability indicators included in the Sustainable Groundwater Management Act (SGMA). Groundwater levels and groundwater storage benefit from an effective demand reduction program in all circumstances. Of all demand reduction practices, land fallowing has the clearest applicability to groundwater levels and storage. Other sustainability indicators, including interconnected surface water, water quality, subsidence, and seawater intrusion, depend on the local hydrogeologic conditions and the specifics of the demand reduction program. For example, a program that targets reducing demand near groundwater connected surface waterways could provide substantial benefits to the interconnected surface water sustainability indicator.

**Table MM13-1. Level of Benefit to the Six Sustainability Indicators Outlined in SGMA.**

| | Six Sustainability Indicators Outlined in SGMA | Applicability* |
|---|---|---|
| | **Depleted Interconnected Surface Water** | ★ |
| | **Lowered Groundwater Levels** | ★★★ |
| | **Water Quality Degradation** | ★ |
| | **Subsidence** | ★ |
| | **Reduced Groundwater Storage** | ★★★ |
| | **Seawater Intrusion** | ★ |

*Notes:

★★★ = Primary Benefit (High Applicability)

★★ = Secondary Benefit (Medium Applicability)

★ = Situational Benefit (Applicability dependent on Location, Site Characteristics, and Aquifer Condition)

## Desired Outcomes or Benefits Resulting from Demand Reduction

The effect of a demand reduction program on overall aquifer health and sustainability indicators depends primarily on net water savings or reduced net depletion. Groundwater Sustainability Agencies (GSAs) and other management agencies usually consider demand reduction programs in coordination with supply augmentation projects to achieve a more balanced portfolio of responses to manage groundwater sustainably. However, agencies that are more dependent on existing groundwater pumping, and have few affordable new supply options, may need to rely much more on demand reduction.

Table MM13-2 summarizes the general types of benefits that demand reduction programs can provide to groundwater sustainability indicators. Demand reduction programs, such as agricultural land fallowing, may be distributed over many small locations across a subbasin. In such instances, the total benefits of all the smaller projects would need to be considered. For water quality, irrigation practices that reduce percolation can reduce the movement of contaminants into groundwater.

**Table MM13-2. Level of Benefit to the Six Sustainability Indicators Outlined in SGMA**

| | Potential Benefits on SGMA Sustainability Indicators | Benefit / Not Applicable | Description of Benefits |
|---|---|---|---|
| | Depleted interconnected surface water | Benefit | Maintaining water levels in the aquifer allows for maintenance of the interconnection to surface water in connected streams, which allows for healthier stream-dependent ecosystems. |
| | Lowered groundwater levels | Benefit | Reduced depletion keeps more groundwater in the aquifer, which maintains groundwater levels. |
| | Water quality degradation | Benefit | Changes in water use and conservation practices may have water quality benefits. For example, fallowing would reduce application of other farm inputs in specific areas, which can affect the quality of recharge from deep percolation of applied water. |
| | Subsidence | Benefit | Maintaining water levels in the aquifer limits the potential for subsidence to occur. |
| | Reduced groundwater storage | Benefit | Maintaining water levels in the aquifer keeps groundwater available in storage. |
| | Seawater intrusion | Benefit | Maintaining water levels in the aquifer provides a natural buffer against seawater intrusion. |

## Potential Impacts

Reducing demand on water can reduce undesirable effects of groundwater use in areas that are already water-stressed and are experiencing undesirable effects due to overuse of groundwater and depleted aquifers. Demand reduction does not have many potential negative impacts on sustainability indicators. However, demand reduction programs can result in economic impacts to water users and linked industries. For example, a land fallowing program would result in less land being farmed, which would affect farming, individuals and third-party businesses that depend on the local farming industry.

Potential impacts resulting from water demand reduction projects or management actions on groundwater sustainability indicators are shown in Table MM13-3.

**Table MM13-3. Potential Impacts Resulting from Project / Management Action.**

| | Potential Impacts on SGMA Sustainability Indicators | Potential Impact / Not Applicable | Mitigation Measures to Address Impacts |
|---|---|---|---|
| | Depleted interconnected surface water | Not Applicable | |
| | Lowered groundwater levels | Impact | Demand reduction under programs such as irrigation efficiency or agricultural land fallowing can affect the location and timing of percolation to groundwater. |
| | Water quality degradation | Not applicable | |
| | Subsidence | Not Applicable | |
| | Reduced groundwater storage | Not Applicable | |
| | Seawater intrusion | Impact | Demand reduction under programs such as agricultural land fallowing can affect the location and timing of seawater intrusion. |

## Use and Limitations

The primary challenge for demand reduction is quantifying the amount of net water savings. Demand reduction must be specified in terms of reducing net depletion. Preliminary water balance calculations should be based on measured parameters, which may include metered water use, reference evaporation, crop type, pump efficiency, groundwater levels, and irrigation system pressure and efficiency measures. This initial step can help avoid confusion about irrigation and urban water use efficiency measures that may reduce gross applied water use but have little or no effect on net water use, and therefore does not reduce net depletion.

Measuring a reduction in net water use requires defining an appropriate baseline. With no demand reduction, the appropriate baseline may be recent water use and field characteristics with any planned supply augmentation included.

Measuring demand reduction requires a monitoring system, which should include measurement of net water use or net depletion. If all applied water that is not consumed returns to the usable aquifer, then net depletion is evapotranspiration (ET) including any additional incidental evaporation. Reducing percolation without changing the ET would not generate any net reduction in water use.

Two options for measuring extraction are: 1) meters, and 2) calculated extraction. Meters can be used to accurately measure gross water extraction. Extraction measurement might be calculated using information on reference ET, crop type, and irrigation efficiency, or by using information on electricity use, depth to water, irrigation system pressure, and pump efficiency. Calculated extraction measures might be less accurate as they require assumptions to be made in calculating the various components. Remote sensing technologies can provide estimates of field-level ET and ET of applied water.

Return flows to groundwater cannot usually be measured directly. Without other basin losses, returns can be estimated as extraction minus estimated consumptive use. This measure supposes that all applied water that is not consumptively used returns to the groundwater. In fact, some might become surface water as springs or stream accretions, and some might flow underground into adjacent groundwater basins. Groundwater models might be used to provide these types of estimates.

Difficulties associated with measurement of returns to groundwater mean that the preferred measure for demand reduction programs is reduced consumptive use and other irrecoverable losses. In basins with allocations that substantially reduce pumping from historical levels, metering may be required due to the uncertainty associated with water balance approaches to estimate pumping. Metering of extraction combined with careful, field-level ET estimates (such as using remote sensing) can substantially reduce the uncertainty of changes in net water use.

Challenges include isolating benefits and impacts of management actions and quantifying water demand savings. Source water composition of water supply may differ throughout the year or from one year to the next, especially during drought conditions. Unmetered use is another limitation that makes it challenging to identify where demand reduction occurs within a system and then relate it to any specific demand reduction measure.

Results of water demand reduction using the monitoring network established during project implementation may indicate that insufficient data are being obtained to evaluate the effectiveness of the water demand reduction measure. These conditions can be addressed by developing and implementing additional monitoring to identify where demand reduction practices can be assessed.

## Relationship to Other Monitoring Methods

Demand Reduction Monitoring Methods are similar to monitoring methods for groundwater allocations and trading. The methods used to track water use and transfers in a groundwater trading program can be the same as the monitoring methods for demand reduction.

## Groundwater Demand Reduction Monitoring

This Monitoring Method potentially applies to a wide range of demand reduction activities. Given the broad range of applicable projects and management actions, these monitoring methods are developed to apply generally to demand reduction activities and their potential effect on groundwater resources.

## Background and Context

Demand reduction program monitoring should include measurements of assess the effects on groundwater resources, and determine the net amount of water saved. For example, if an agricultural field is fallowed in a closed basin, the net water savings would be the evapotranspiration of applied water plus any other unrecoverable losses. Eliminating percolation of irrigation water back to the usable aquifer is not a savings if the demand reduction project does not change the net extraction.

Physical groundwater aquifer monitoring metrics relate to groundwater elevation (to make sure that demand reduction results in water levels increasing or maintained) and groundwater quality (to make sure that no unintended impacts due to moving of constituents of concern occur) in the vicinity of the demand reduction activities footprint. If demand reduction occurs in an area of seawater intrusion, or subsidence, specific monitoring to assess these two sustainability indicators needs to be considered.

Examples of project-specific monitoring for the purpose of sustainable groundwater requirements for different types of demand reduction activities include:

– **Agricultural water use efficiency**: Measures that would generally reduce the amount of water applied to a crop including efficient irrigation, on-farm water management, irrigation scheduling, and crop changes.

  *Monitoring - quantify the change in net water use (evapotranspiration of applied water) specifically as it applies to groundwater use.*

– **Agricultural land repurposing (crop changes or fallowing):** Measures that would change crop types or repurpose previously irrigated lands to non-irrigated uses.

  *Monitoring - quantify the change in net water use (evapotranspiration of applied water) specifically as it applies to groundwater use.*

– **Conveyance water loss reduction**: Projects designed to reduce leaks, seepage, spills, or other losses from the delivery system.

  *Monitoring - quantify the reduced depletion by estimating reduced losses less reduced percolation to usable groundwater.*

– **Urban Water Conservation:** Urban water conservation and water efficiency measures such as:

  - **Water-efficient appliances:** Programs that assist or otherwise incentivize businesses and individuals to upgrade appliances.

    *Monitoring – The change in water use can be approximated based on the water-saving volume per appliance, and the number of appliances and frequency of use per household. Monitoring should calculate the change in consumptive use and irrecoverable losses.*

  - **Drought-tolerant landscape programs**: Programs that incentivize, or require, businesses and individuals to reduce outdoor irrigation.

    *Monitoring – The change in water use can be approximated based on the number of homes upgrading to drought-tolerant landscapes and the area of improvement. Monitoring should calculate the change in evapotranspiration and irrecoverable losses of applied water in outdoor landscaping.*

  - **Behavior-based measures:** Programs could include water pricing mechanisms, conservation messaging, or norms-based messaging.

    *Monitoring – The change in water use can be approximated based on household meter data. Monitoring should calculate the change in consumptive use and irrecoverable losses. Use data to relate the change in consumptive use to changes in groundwater conditions over time.*

- **Infrastructure upgrades:** Capital Improvement Projects that allow agencies to use groundwater and surface water more efficiently.

  *Monitoring – The change in water deliveries can be approximated using district meter data. For the purposes of sustainability, monitoring should calculate the change in consumptive use and irrecoverable losses.*

Monitoring requirements will be tailored to the specific demand reduction project. The important requirement for monitoring is to be able to measure the reduction in net depletion. It is noted that quantifying irrecoverable losses may be quite difficult and imprecise. Estimates may need to be refined over time as more data are collected.

## A Step-by-Step Guide to Applying the Demand Reduction Monitoring Method

1. **Safety plan:** All projects with fieldwork related activities should produce a Safety Plan. Planning for fieldwork and availability of access to the site, such as monitoring wells, is necessary to maintain project safety. Demand reduction projects may require a Safety Plan to address these and other potential safety concerns.
2. **Area of Interest:** Identify the purpose of the demand reduction program (i.e., what groundwater sustainability indicators are being addressed?) and where the program will be targeted.
3. **Monitoring Plan:** Develop a monitoring plan that will apply to the specific demand reduction program and project area and define program baseline conditions.
   - The existing GSP monitoring wells may be helpful for monitoring broader subbasin conditions. Additional groundwater monitoring may be needed to better assess effects from implementation of demand reduction activities. Additional activity-specific monitoring is required for targeted demand reduction projects that allows water managers to measure changes in net groundwater use attributable to the program. The plan must consider whether metering will be available, and if not, how consumptive use can be calculated at the field level.
   - The monitoring plan must also define baseline conditions used to measure reduced water use. Baseline conditions must carefully define how water would have been used in the absence of the demand reduction program.
4. **Data collection:** Collect data required to support the implementation of the demand reduction program, baseline conditions, and associated monitoring.
5. **Implement the demand reduction project:** Implement the demand reduction program. This may be done through an initial pilot program.
6. **Monitoring:** Monitor the changes in net water use and groundwater conditions and update the demand reduction program as needed.
   - Assess if data gaps exist and if additional monitoring is necessary. Use monitoring to improve estimates of water balance, such as percolation and irrecoverable losses.
   - Continue to monitor groundwater conditions as required for the Groundwater Sustainability Plan (GSP), if applicable.
   - Monitor program implementation and effects on groundwater conditions and applicable sustainability indicator metrics.
7. **Review and Adaptive Management:** Review data at least annually to determine if and/or how the demand reduction program should be updated. Concurrently, review broader GSP implementation, other projects, and progress towards sustainable management criteria. Expand or refine monitoring network adaptively, as needed.
8. **Reporting:** The monitoring data should be reported annually to the GSA to support demand reduction program monitoring and SGMA reporting requirements.
   - Upload project-specific monitoring data to the DWR SGMA data portal on an annual basis. This step will need to be coordinated with and completed by the GSAs.

## Data and Protocols - Fundamentals

Demand reduction projects should be designed to achieve a reduction in net groundwater use. Monitoring should be developed so that the GSA can evaluate the net water savings and adaptively manage the program, as well as determine its impacts or benefits on groundwater sustainability metrics.

Protocols for specific demand reduction measures will need to be investigated by the grantee to find the most recent data and regional standards for the specific activity or management action. DWR has published the Urban Water Management Plan Guidebook (2020), which provides recommendations for demand management measures and how they could be applied. However, as described earlier, for the purposes of groundwater management, the demand reduction program must result in a reduction in net groundwater use.

### Data Analysis and Reporting

The GSA or agency responsible for implementing the demand reduction program should analyze data periodically and use that to improve the program.

1. **Analyze monitoring data:** Monitoring data should be used to evaluate the effectiveness and performance of the demand reduction management actions, determine any limiting factor(s) on performance, and identify options for improving performance if needed. This assessment also includes evaluating any new stakeholder concerns once the project has been implemented.
2. **Prepare reports and manage data:** Reports and data management includes compliance with regulatory and grant requirements and providing data to DWR, which is addressed in the Data Management and Monitoring Method [MM-12]. Generally, data will be uploaded to the DWR system annually and progress on project implementation and monitoring will be provided in the GSP Annual Report. A full assessment of the project performance will be provided in the GSP 5-Year Assessment Report.

### Data Standards

Groundwater, surface water, and water quality monitoring data should conform to the technical and reporting standards of the California Water Code (CWC) §352 *et seq*.

Groundwater levels - Groundwater elevation measurements should be recorded relative to a consistent vertical datum.

Water budget – the water budget should be developed using best practices, consistent with DWR GSP Water Budget Best Management Practices (BMP). This should be used to calculate the net change in consumptive water use and must account for all changes under the demand reduction program.

Groundwater quality - Concentrations of groundwater quality constituents of concern should be compared to maximum contaminant levels available from the SWRCB.

### Key Protocols

The following protocols should be followed for required monitoring:

- Standard groundwater level and groundwater quality monitoring protocols as described in DWR's Best Management Practice (BMP) 1 Monitoring Protocols, Standards, and Sites (DWR, 2016).
- Guidelines for establishing monitoring networks and resolving data gaps to reduce uncertainty are provided in DWR's BMP 2 Monitoring Networks and Identification of Data Gaps (DWR, 2016).
- Standard water budget development as described in DWR's Best Management Practice (BMP) 4 Water Budget (DWR, 2016).
- Technical and reporting standards included in CWC §352 *et seq*.

## Example of Demand Management Reductions Applications

### Agricultural Land Repurposing Program

*Figure MM13-1. Madera County Land Repurposing website.*

**Location:** County of Madera GSA, Madera Subbasin

**Year:** 2021 – Present

**Description and Relevance:** In 2018, the GSAs comprising Chowchilla and Madera Subbasins, and a small portion of the Delta Mendota Subbasin, began developing comprehensive, coordinated GSPs to comply with requirements of SGMA. The Madera County GSA is responsible for county lands in Chowchilla, Madera, and Delta Mendota areas. These lands are fully groundwater dependent, without access to district surface water supplies. The Madera County GSA developed a combination of water supply and groundwater recharge projects to bring its groundwater use into balance and avoid large reductions in agricultural demand.

The GSA is developing a land repurposing program to shift currently irrigated lands into other, non-irrigated uses. The initial demand reduction program was developed with extensive stakeholder input over an 18-month period between 2020 and 2022. The study inventoried current irrigated lands in the Madera County GSA and identified options for multi-benefit land repurposing opportunities. An incentive structure with a range of financial payments for voluntary agricultural land conversion or preservation in specific areas based on the land categories identified by the analysis was developed. The incentives were linked to water use by parcel and developed consistent with other projects and management actions (e.g., the Madera County GSA recharge program).

The program is currently moving into the implementation phase. This includes refining agricultural land incentive payments, multi-benefit land repurposing options, and setting rules for program participation.

Monitoring will be achieved using the GSA's remote sensing water tracking system, Irriwatch. Irriwatch is able to track evapotranspiration of applied water on a parcel basis. This remote sensing system is linked to an established groundwater application by the GSA. Since the monitoring system measures evapotranspiration and water use is defined relative to an allocation (which is also based on the evapotranspiration of applied water), the monitoring is able to track changes in net water use attributable to the program.

**Links to Resources:** https://www.maderacountywater.com/land-conservation/

### Valley Water Urban Demand Reduction

**Location:** Santa Clara County

**Year:** 1991 - present,

**Description and Relevance:** Santa Clara Valley Water District (Valley Water) is the primary water resources agency for 1.9 million residents, covering 1,300 square miles in Santa Clara County. Valley Water serves water to 13 local retail water agencies including the cities of San Jose and Santa Clara. About half of the County's water supply currently comes from local surface water, groundwater, and recycled water sources. The remainder comes from imported water sources.

Conservation, or demand reduction programs implemented in the region include: (1) Commercial and Multi-Family Dwelling High Efficiency Toilet Direct Installation, (2) Graywater Laundry-to-Landscape Rebate and Direct Installation (3) Landscape Rebates (4) Submeter Rebates, and (5) Water Wise Do-It Yourself Kits and Surveys. Conservation measures helped Valley Water meet water use reduction targets of 20% in 2014 and 30% in 2015. In 2019 total water use was about 295,000 acre-feet, while demand reduction programs conserved approximately 75,600 acre-feet. Going forward, long-term water conservation is a key component of Valley Water's water supply management strategy. Valley Water's Water Supply Master Plan outlines a strategy to provide a reliable supply of water through 2040. Water demand within Valley Water is projected to be approximately 335,000 acre-feet per year by 2040 with a water conservation target of 109,000 acre-feet per year.

The targeted benefits of demand reduction to Valley Water are increased groundwater levels, limited subsidence, and available groundwater in storage for use in critically dry periods. Some of Valley Water's programs such as rebates for landscape conversion, clearly reduce net water use. The effect of other programs, such as replacing indoor fixtures and appliances, on net water savings are not as clear, though they save operational costs and reduce return flows to the wastewater system.

The graphical depiction shown below, from Valley Water's 2021 Groundwater Management Plan, shows the general relationship between population, groundwater elevation, and land subsidence over time. As shown in the graphic, water conservation or demand reduction, especially since 2012, helped Valley Water rapidly recover groundwater levels to pre-drought levels following the 2012-2016 drought.

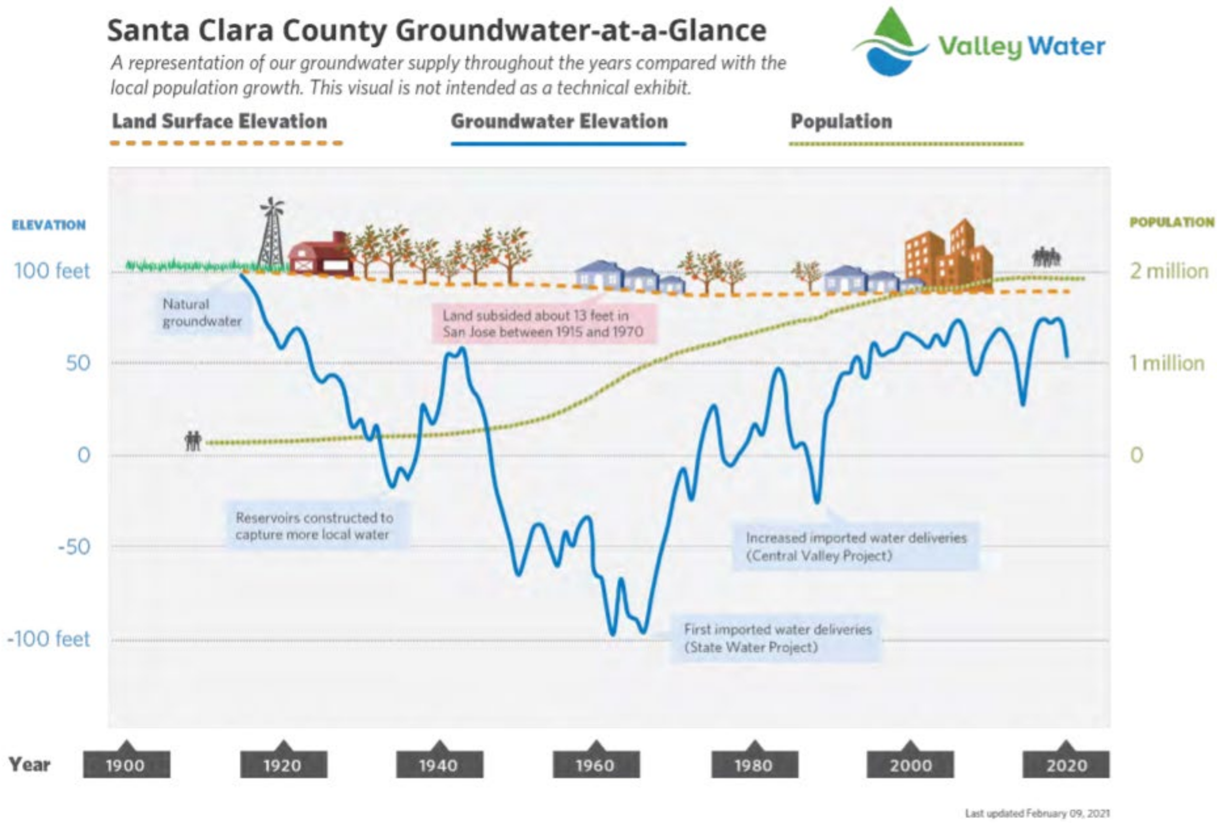


**Figure MM13-2. Santa Clara County Groundwater History Timeline** (Valley Water, 2021)

### Links to Resources:

Valley Water, 2021. Groundwater Management Plan for the Santa Clara and Llagas Subbasins. https://s3.us-west-2.amazonaws.com/assets.valleywater.org/2021_GWMP_web_version.pdf

Valley Water, 2021. Water Conservation Strategic Plan. https://s3.us-west-2.amazonaws.com/assets.valleywater.org/Valley%20Water%20WC%20Strategic%20Plan.pdf

## Source References

California Department of Water Resources. 2016. *Best Management Practices for the Sustainable Management of Groundwater, six-part series (BMP 1 Monitoring Protocols Standards and Sites, BMP 2 Monitoring Networks and Identification of Data Gaps, BMP 3 Hydrogeologic Conceptual Model, BMP 4 Water Budget, BMP 5 Modeling, and BMP 6 Sustainable Management Criteria DRAFT).* Sacramento (CA): California Department of Water Resources. [Website]. Viewed online at: https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents.

Public Policy Institute of California. 2020. *A Review of Groundwater Sustainability Plans in the San Joaquin Valley.* San Francisco. (CA): PPIC Water Policy Center. [Website]. Viewed online at: https://www.ppic.org/wp-content/uploads/ppic-review-of-groundwater-sustainability-plans-in-the-san-joaquin-valley.pdf

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SUSTAINABLE GROUNDWATER MANAGEMENT (SGM) GRANT PROGRAM

# Groundwater Trading Monitoring Method MONITORING METHOD [MM-14]

**The Groundwater Trading Monitoring Method was written as a synthesis and informational piece for DWR staff, to be updated for future use, as needed.**

SUSTAINABLE GROUNDWATER MANAGEMENT (SGM) GRANT PROGRAM

## MONITORING METHOD [MM-14]

# Groundwater Trading Monitoring Method

| | |
|---|---|
| **Project / Management Action Type** | Groundwater trading is an evolving approach to sustainable groundwater management where willing groundwater users (usually growers) within a managed basin are allowed to sell all or part of their groundwater allocation to others in the basin willing to pay for it. Trading does not necessarily reduce the total amount of water pumped within a basin but rather allows growers and other users to redistribute the total pumping amount to help shift pumping away from areas of groundwater decline or other issues to areas with better groundwater conditions. |
| **Similar / Related Project Types** | Examples of water markets and groundwater allocations and trading can be found in adjudicated basins in California and in other western states, such as Arizona, Colorado, and Nebraska. Water trading has also been successfully used in the Murray-Darling Basin in Australia. |
| **Primary Metrics** | Gross and net (of recharge) volume traded and pumped by location and time. Monitoring of localized groundwater levels to identify potentially excess drawdown and impacts on other uses. Groundwater quality and other metrics may be applicable situationally and are addressed by other Monitoring Methods. |
| **Measurement Units** | Gross and net acre-feet traded and pumped. Feet of groundwater level change; concentrations of applicable water quality constituents of concern. |
| **Primary Beneficial Users** | Municipal and domestic water supply (MUN)<br>Agricultural water supply (AGR) |

## Groundwater Trading Overview

Groundwater trading is an evolving approach to sustainable groundwater management that gives water users more flexibility to respond to allocations or other pumping rules implemented to help bring a groundwater basin into a sustainable condition. A groundwater trading program enables willing sellers to trade part or all of their **groundwater allocation** to others who are willing to pay for it.

This concept has been used in adjudicated basins in California (such as Chino and Mojave basins) and is currently being piloted and/or studied by a number of Groundwater Sustainability Agencies (GSAs) to meet Groundwater Sustainability Plan (GSP) Regulations. A groundwater trading program can only be implemented where pumping is limited (as with allocations), so that entities know how much they have available to pump or trade. Pumping must be measured to track use of the owner/operator's allocation and to verify where and when traded water is being used. Additionally, a groundwater trading program should be integrated with other policies, projects, and management actions implemented under a GSP. Implementation by, or coordination with, the applicable management entities (such as the **Watermaster Program** or GSAs) is needed to ensure consistency with other management actions and to avoid undesirable results.

A trading program on its own does not generally reduce total groundwater use (a limit in the allocation would create the water use reduction regardless of how the water was traded). The benefit of trading is to reduce economic costs of allocation, and to shift areas of pumping within a basin, not to reduce total pumping. Trading could occur within a formal water market or within informal markets. Informal trading could be a one-to-one private trade or a group of water users forming a "partnership" to manage a shared allocation.

Groundwater trading is encouraged in the Governor's 2020 California Water Resilience Portfolio. Action 3.6 outlined the following:

> *"Create flexibility for groundwater sustainability agencies to trade water within basins by enabling and incentivizing transactional approaches, including groundwater markets, with rules that safeguard natural resources, small farmers, and disadvantaged communities."*

In March 2021, the California Water Commission (CWC) was asked to *"utilize its public forum to gather expert and public input and investigate what role California agencies should take to support in-basin groundwater trading that protects natural resources, disadvantaged communities, and small- and medium-size farms as local agencies turn to groundwater trading as a flexible tool to help them bring basins into sustainable conditions"* (CWC, 2022). This effort culminated in a White Paper, which was released in May 2022. This White Paper provides insights on stakeholder perspectives and provides an overview of challenges and considerations for successful groundwater trading programs in California.

**KEY TERMS**

**Groundwater allocation** is an amount of groundwater use that has been defined and quantified over a period, usually one year, and can be assigned or distributed to specific users within a basin.

The **Watermaster Program** was established by the state in 1924, to ensures that water is allocated according to established water rights as determined by court adjudications or agreements by an unbiased, qualified person, thereby reducing water rights court litigation, civil lawsuits, and law enforcement workload. It also helps prevent the waste or unreasonable use of water.

The **sustainable yield** means the maximum quantity of water that can be withdrawn annually from a groundwater basin without causing undesirable results

## The Role of Allocation

A groundwater trading system cannot work unless groundwater pumping is limited and users know how much they have available to them over a defined period (normally a year) at a specific location (normally a well/parcel or group of wells associated with a user's operation). Groundwater allocations made by a GSA, along with trading rules and other policies, may specify how much water can be pumped, when it can be pumped, and from where it may be pumped, as well as who can own an allocation, how many allocations one may own, where those allocations can be used, and more (CWC, 2022). Regardless of whether trading is allowed, the total of all allocations must align with basin management objectives, as outlined in the basin's GSP(s), and reflect the **sustainable yield** of the basin (EDF, 2017).

Under an allocation, allowable groundwater pumping is apportioned to individual parcels, wells, or entities (such as, for example, farming operations with multiple parcels and wells). By defining the quantities of groundwater available to individual users, an allocation can incentivize demand reduction, development of new recharge opportunities, and trading.

Implementing an allocation does not necessarily result in reducing groundwater use. For example, if a user's allocation is greater than historical or expected use, then the user's groundwater use is not constrained. In the context of GSP implementation, the allocation is typically tied to the sustainable yield of the subbasin. When the sustainable yield is less than current pumping, the effect of an allocation is an overall reduction in net groundwater use.

Figure MM14-1 illustrates how growers under an allocation could willingly trade water.

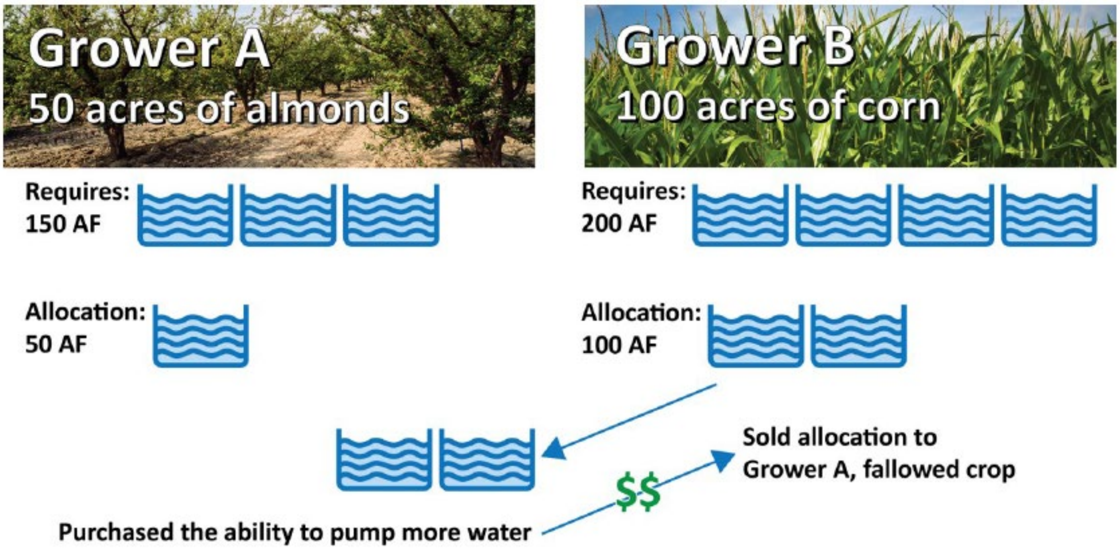


**Figure MM14-1. Illustrative example of groundwater trading in an agricultural setting** (California Water Commission, 2022)

## Groundwater Trading for Sustainable Groundwater Management Act Implementation

**Groundwater trading or groundwater markets** are in the early stages of implementation by several GSAs, and under active consideration by others. As GSAs look for innovative approaches to manage their transition to sustainable conditions, and with guidance and support by the state, more GSAs or water districts may look to groundwater trading as a way to lower costs to users and as a tool to help achieve groundwater sustainability. The U. S. Bureau of Reclamation has supported the study of groundwater trading through its WaterSmart Water Marketing Strategy Grants program[2]. The state expects to continue providing support for the Sustainable Groundwater Management Act (SGMA) implementation, and grant applications may include some of the activities needed to implement groundwater trading.

The California Department of Water Resources' (DWR's) current Project Solicitation Package for SGMA implementation grant funding specifically excludes funding for water markets and trading programs. However, funding can be requested for activities that serve broader implementation needs and could also support a trading program. These could include for example, subject to grant program guidelines:

– Installing monitoring equipment.
– Collecting detailed data on water levels and water quality.
– Developing modeling capability to assess potential effects with changes in groundwater pumping.
– Installing flow meters on each well.
– Conducting stakeholder outreach and education.

[2] https://www.usbr.gov/watersmart/watermarketing/index.html

The purpose of this Monitoring Method is to provide general context on monitoring and reporting standards to assess the effectiveness or impacts of groundwater trading programs within basins managed by GSA's. The applicability of trading programs to the sustainability indicators is presented in Table MM14-1.

**Table MM14-1. Level of Benefit to the Six Sustainability Indicators Outlined in SGMA**

| | Six Sustainability Indicators Outlined in SGMA | Applicability* |
|---|---|---|
| | Depleted Interconnected Surface Water | ★ |
| | Lowered Groundwater Levels | ★ |
| | Water Quality Degradation | ★ |
| | Subsidence | ★ |
| | Reduced Groundwater Storage | ★ |
| | Seawater Intrusion | ★ |

*Notes:

★★★ = Primary Benefit (High Applicability)

★★ = Secondary Benefit (Medium Applicability)

★ = Situational Benefit (Applicability dependent on Location, Site Characteristics, and Aquifer Condition)

## Monitoring Objectives

Groundwater trading does not reduce total pumping but can shift the location and timing of pumping based on the outcomes of trading. If certain directions or volumes of trades would create or exacerbate an undesirable result, restrictions should be built into the trading rules and monitoring used to verify that the rules are followed, and the undesirable result can be addressed. An economic analysis of likely outcomes from trading can inform the likely timing, volume, and even location of trading under different water market designs. This can be linked with GSP groundwater modeling and monitoring to evaluate the potential for unintended outcomes. Groundwater market trading rules can then be refined to avoid such outcomes.

The primary objective of monitoring trades is to verify that allocations and trading rules are not being violated. Monitoring can also be used to adjust trading rules over time when unanticipated issues arise. Monitoring can help identify localized issues such as accelerated subsidence, streamflow depletion, or water quality changes that may be exacerbated by locational shifts in pumping as a result of trades.

## Desired Outcomes or Benefits Resulting from Groundwater Trading

By providing groundwater users additional flexibility to respond to reductions forced by an allocation, trading within a basin can reduce the adjustment costs imposed by SGMA implementation. However, that flexibility should not come at the cost of exacerbating undesirable outcomes. Groundwater trading should be coordinated with other projects and management actions specified in a GSP. Rules and restrictions should be built into the trading program that are tied to the sustainability indicators. By using existing groundwater allocations and wells to offset pumping in parts of the basin that may be overdrafted, groundwater trading can help stabilize groundwater levels and avoid undesirable results. Groundwater trading rules can be designed to help shift groundwater pumping away from areas that have issues associated with seawater intrusion or subsidence.

**Groundwater trading/market** is an institution that allows individuals to voluntarily buy, trade, exchange, or sell some aspect of the right to pump and use groundwater (e.g., an allocation).

Table MM14-3 shows the potential benefits of groundwater trading projects relative to background conditions.

**Table MM14-2. Potential Benefits Resulting from Project / Management Action.**

| | Potential Benefits on SGMA Sustainability Indicators | Benefit / Not Applicable | Description of Benefits |
|---|---|---|---|
| | Depleted interconnected surface water | Benefit | Small or incidental benefits might be achieved through careful groundwater trading rules or restrictions that incentivize trades away from a problem area, thus reducing interconnected surface water depletions. |
| | Lowered groundwater levels | Benefit | Small or incidental localized benefits might be achieved through careful groundwater trading rules or restrictions that incentivize trades away from a problem area, thus reducing lowering of groundwater levels. |
| | Water quality degradation | Benefit | Groundwater trading could help to improve water quality if trading rules result in a shift of pumping away from impacted water quality areas. |
| | Subsidence | Benefit | Groundwater trading could benefit areas that are overdrafted and experiencing subsidence issues if trading rules result in a shift of pumping away from impacted areas. |
| | Reduced groundwater storage | Benefit | Groundwater trading rules could benefit areas within a basin that are significantly overdrafted. |
| | Seawater intrusion | Benefit | Reallocation of groundwater through trading could benefit areas that are overdrafted and experiencing seawater intrusion. |

## Potential Impacts

Groundwater trading does not provide an additional source of water but merely shifts the location and perhaps timing of groundwater pumping within the same basin. This creates the potential for impacts, especially in the area where pumping increases due to extraction of traded water. Localized concentration of extraction can cause or exacerbate impacts in any of the six sustainability indicators and potential impacts resulting from groundwater trading projects are highlighted in Table MM14-3.

Some of impacts may be anticipated when the market is set up, so trading rules or restrictions can be included. For example, these could include limits to total annual extractions (including trades) in a defined problem zone, or directional trading ratios that incentivize reduced pumping in a problem zone. As the market is implemented, trading should be monitored to see if the rules are effective at avoiding impacts or if unanticipated impacts appear. Based on the monitoring information, the rules may need to be tightened or changed.

Groundwater trading could increase pumping in situations where allocations are unused. Unused allocations could therefore be traded, allowing for more pumping in the basin that otherwise would not have occurred. Without trading, some allocation may be unused if some individual allocations are more than irrigation requirements, or if irrigation ceases due to agronomic or business factors.

**Table MM14-31. Potential Impacts Resulting from Project / Management Action.**

| | Potential Impacts on SGMA Sustainability Indicators | Impact / Not Applicable | Mitigation Measures to Address Impacts |
|---|---|---|---|
| | Depleted interconnected surface water | Possible Impact | Groundwater trading may affect streamflow depletion where surface water is interconnected with groundwater if groundwater trading increases pumping near a stream. All interconnected waters should be monitored to mitigate and avoid impacts. |
| | Lowered groundwater levels | Possible impact | Monitoring should be done to assess potential impacts to groundwater levels in areas where traded water is being extracted. |
| | Water quality degradation | Possible impact | Changes in pumping patterns may affect groundwater flow in a basin and mobilize constituents of concern that may move to parts of the basin that did not previously have groundwater quality issues. Monitoring should be done to assess water quality in supply wells used by beneficial users near the trading area. |
| | Subsidence | Possible impact | Increased pumping in a subsidence-prone area may have unintended effects due to trading. Monitoring should be done to evaluate subsidence potential in the aquifer where water is being traded. |
| | Reduced groundwater storage | Possible impact | Monitoring should be done to assess potential impacts to groundwater storage in areas where traded water is being extracted. |
| | Seawater intrusion | Possible impact | Monitoring should be done to identify potential seawater intrusion caused or exacerbated by extraction of traded water. Trading rules may be modified to mitigate or eliminate the impact. |

## Use and Limitations

A groundwater trading program can only be as good as the associated governance systems and rules. To have strong governance, the trading program should provide transparency, oversight, monitoring, enforcement, and protection, and consider all beneficial users of groundwater that may be affected by the trading.

Disadvantaged Communities and Groundwater Dependent Ecosystems (GDEs) often lack the purchasing power or representation to acquire water. Ensuring sufficient supplies and protections for each of these vulnerable groups is essential. Therefore, adequate allocations of groundwater for such entities or beneficial uses should be assured before a trading program is developed (Environmental Defense Fund, 2017).

Groundwater well metering, or other measurement, can be costly. Groundwater trading shifts the extraction of groundwater to a different area and/or time within a basin. Therefore, trading should be restricted or limited as needed by market rules regarding, for example, direction of trades (i.e., pumping can be traded out of an area but not into it) or total extraction within a zone if such would cause undesirable results. An overall water balance and model of the trading areas should be analyzed to mitigate any impacts and assess that the trading of groundwater resources can provide benefits (or does not negatively impact) the beneficial uses.

Consistent with the flexibility of local control spelled out in SGMA, robust trading rules must incorporate appropriate hydrologic relationships, economic conditions, legal obligations, and community-specific needs.

No two groundwater trading programs are identical, and each must be tailored to meet the specific objectives and needs of the local groundwater basin. While trading programs may function across GSA boundaries, the rules and regulations governing them should appropriately reflect local sustainability goals and hydrologic relationships, and socioeconomic and ecosystem needs (Environmental Defense Fund, 2017). Groundwater pumping, allocation, and trading must comply with existing **water rights** and laws in California. These include the doctrines of reasonable and beneficial use of water and the correlative rights of overlying groundwater users. Implementing an allocation within a basin has perhaps the greatest potential for a water rights challenge. Developing groundwater allocations that are consistent with groundwater law and incorporate all beneficial users' needs in a basin is challenging since there is very little guidance in California to date (EDF, 2017).

Water trades within a basin could trigger legal challenges if they are claimed to impose negative consequences on other parties or uses. For example, a trade could concentrate pumping in a small area and be claimed to interfere with nearby wells or affect streamflows. Groundwater trading rules should be designed to avoid or mitigate such effects. Especially, the trading rules should consider the potential for **third-party impacts** on beneficial uses that do not have the capacity to litigate for themselves. These parties could be disadvantaged communities, GDEs, or endangered/threatened species.

## Groundwater Trading Monitoring

In order to implement groundwater trading, adequate measurement of groundwater pumped by well or parcel is required. GSAs are approaching the monitoring of groundwater use in different ways. Some are relying on a water balance approach based on land use (e.g., standard crop consumptive use factors, irrigation efficiency and return flow estimates, and effective precipitation); others are augmenting the water balance with remote sensing estimates of consumptive use; and others are planning to implement well metering. For groundwater trading, accurate measurements are required for the traders to verify that the terms of trade are followed, and for both traders and the GSA to track use of allocations.

Monitoring the effects of a groundwater trading program will be needed to make sure that sustainable management criteria are not violated (i.e., undesirable results do not occur). At program initiation, the established GSP monitoring networks may be suitable to monitor the benefits and impacts for at least some of the sustainability indicators, if located in areas that may be directly impacted by trades. Monitoring of groundwater levels is expected in all cases, and depending on the GSA and its indicators, monitoring could also include water quality, subsidence, and seawater intrusion. If one or more indicators show an undesirable trend, additional monitoring (more sites or greater frequency) may become necessary.

All of the Sustainability Indicator Improvements Monitoring Methods (MM-07 to MM-10) may be applicable to track potential effects of groundwater trading. Monitoring of groundwater pumping and allocation accounting can be incorporated into the protocols of Data Management and Monitoring (MM-12).

## Background and Context

### Monitoring of Pumping and Trades

Monitoring and tracking the volume of water trading is crucial to ensure the overall water balance of the basin is not affected and local impacts can be managed. The volume of traded water must be monitored. It might be possible to measure pumped and traded water use without metering. For example, pumping might be calculated from electricity use and pump efficiency information or through remote sensing methods. Metering of wells that pump water for trades could be required.

### Monitoring for Sustainability Indicators

Groundwater levels and groundwater quality monitoring should be conducted for groundwater trading programs. Monitoring groundwater levels and groundwater quality allows the project proponent to measure total progress toward sustainability and water quality goals. These measures are not an indicator for water trading alone as they are affected by all management actions as well as annual hydrology and economy-driven land use changes. However, analysis of the locations of impacts may suggest that trading has contributed to them. Groundwater level monitoring should include wells installed within the aquifer zone that is being pumped for the trading or transferring of groundwater to identify project benefits and impacts.

If trading appears to be causing or contributing to localized impacts, additional sites or more frequent measurements may be warranted. For example, a local concentration of trade-induced pumping groundwater may occur near a basin boundary or near a GDE, which may suggest additional groundwater level and quality monitoring be implemented. Prior to starting a groundwater trading program, groundwater levels and quality in the potential new pumping area should be assessed to provide a baseline for parameters that could be worsened by trading.

### Additional useful monitoring

A calibrated groundwater model can be used to estimate the total water budget with the changes in pumping schemes in the basin and also evaluate any potential effects on nearby beneficial users. This can be used to measure outcomes after a groundwater trading program is developed and implemented. Prior to implementation, it can also be linked to a calibrated economic model to support groundwater trading program development (e.g., evaluate likely volumes, location, and timing of trades under different program rules, and adjust those rules as needed).

In some cases, other sustainability indicators might benefit from groundwater trading programs. Monitoring for the depletion of interconnected surface water, subsidence and seawater intrusion sustainability indicators are discussed in other Monitoring Methods.

## A Step-by-Step Guide to Applying the Groundwater Trading Monitoring Method

1. **Safety plan:** All projects with fieldwork related activities should produce a Safety Plan. Planning for fieldwork and availability of access to the site, such as reading meters and monitoring wells, is necessary to maintain project safety. Groundwater trading projects may require a Safety Plan to address these and other potential safety concerns.
2. **Area Identification:** Identify the footprint of the area that will be subject to groundwater pumping for the trading program and the specific lands and wells that will be used for the trades.
3. **Identify how water use on lands or wells involved in trading will be calculated**: Normally, pumping will already be metered to support enforcement of allocations.

   If not, a water use measurement plan will be required that is sufficient for the types of trades allowed. If land idling is used to provide water for trade, then inspection of idled land may be sufficient and additional measurement at the source not required. Total water requirement by crop and irrigation type can be estimated, or pumping might be estimated from electricity use and pump efficiency, but potential accuracy of these measurement methods must be addressed.
4. **Monitoring Plan:** Develop a monitoring plan to establish a baseline for the footprint area
   - Identify existing monitoring wells that may be sufficient to use for this evaluation using GSP wells if applicable.
   - Identify monitoring protocols and follow GSP monitoring protocols if applicable.
5. **Data collection:** Collect background groundwater level and quality data prior to the start of the trading program. Collecting seasonal data for up to 1 year prior to project implementation is useful for establishing a baseline. Note: The location of the monitoring network should be easily accessible such that gaining access to the site does not inhibit gathering and downloading data (refer to Step 1).
6. **Monitoring:**
   - Track the volume of water that is pumped and traded in the footprint area
   - Monitor groundwater levels at monitoring wells and conduct water quality testing where pumping is increased by trades.
7. **Assessment of Impacts:** Review all monitoring data at least annually for evaluation of undesirable results and to assess that the claimed quantities of water trading are not exceeded. Assess if groundwater trading in the basin helps stabilize water levels and does not affect water quality. If part of a GSA, the assessment will be included in its annual report.

8. **Assess if data gaps exist:** Determine if additional monitoring is necessary to better evaluate the groundwater trading effects on groundwater sustainability.
9. **Reporting:** Report amounts traded and pumped, by location and timing, to the GSA at a frequency sufficient to track pumping and use of allocation for basin management. Report other monitoring data to the basin's GSA(s) at least twice per year based on SGMA and GSP requirements.
    - Upload project-specific monitoring data to the DWR SGMA data portal on an annual basis. This step will need to be coordinated with and completed by the GSA(s). (See Data Management and Monitoring Method)
10. **Adaptive Management:**
    - Expand or refine monitoring network and frequency adaptively, as needed if trading outcomes indicate potential sustainability impacts.
    - Modify trading rules and restrictions as needed to mitigate or avoid impacts.

## Data and Protocols - Fundamentals

A groundwater trading program needs to be based on:

- Accurate measurement of water use in areas with limiting water use allocations.
- Coordination with SGMA requirements and relevant GSAs.
- Good initial aquifer data and a solid GSP that includes basin information.
- An agreed upon water budget with water accounting.
- An understanding of potential impacts on local communities.

Groundwater trading monitoring typically consists of measuring pumping at participating traders' wells and tracking that against their allocations. Potential impacts of trading may involve changes in groundwater levels, groundwater quality impacts, and other sustainability indicators based on where and when trades are occurring. However, separating out the effect of one or more trades from the effects of other projects and actions (e.g., from natural hydrologic variability or from unrelated land use changes) may be challenging. Table MM14-4 provides an example list of monitoring parameters that can be used in reporting and understanding the effects of a trading program in a quantifiable way over time. The fundamental monitoring methods for groundwater trading programs include the following:

- Volumes and flow rates of extracted water from any well participating in trading should be measured to an acceptable level of accuracy, typically achieved by using a flow meter installed at the wellhead. If other measurement is used, such as remote sensing, it should be developed at an acceptable level of accuracy as well.
- Aquifer groundwater level monitoring using wells or piezometers installed in the saturated zone for evaluating changes in groundwater levels and gradients. Groundwater levels are measured manually using electrical sounders and automatically using pressure transducers lowered into and/or installed in the monitoring wells and piezometers. Groundwater level monitoring protocols are provided in the Department of Water Resources (DWR) Best Management Practices (BMP) 1 Monitoring Protocols Standards and Sites (DWR, 2016). The use of dataloggers in association with pressure transducers allows automated collection and storage of water level measurements at frequent intervals.
- Water quality sampling of source water extracted water, and monitoring wells to evaluate water quality changes due to extraction cycles. Water samples can be collected directly from a tap at the wellhead during extraction and from this discharge location of the demand water. Groundwater quality monitoring in dedicated observation wells should follow protocols provided in DWR's BMP 1 Monitoring Protocols Standards and Sties (DWR, 2016).

**Table MM14-4. Example Data Monitoring Report (Generally Annually)**

| **Monitoring Reporting** | |
|---|---|
| Extraction Basin | XX Basin |
| Pumped/Extracted Basin-wide Groundwater Volume | XXX AF |
| Basin-wide Groundwater Volume of water traded | YYY AF |
| Well # and pumping (List all wells that pumped traded water) | +/- ZZZ ft / +/- ZZZ ft |
| Average Groundwater Level Change – average | Ft Change Q ft |
| Footprint Groundwater Level Change – average | Ft Change R ft |
| Maximum Impact of Trading on Basin Depletion | +YYY/XXX |
| Potential Impact of Trading in Footprint Area | +AAA/ZZZ |
| Incurred Monitoring Costs | $XXX |

## Data Analysis and Reporting

1. **Analyze monitoring data:** Monitoring data should be used to track traded amounts relative to pumping allocations and to evaluate the effectiveness and performance of the trading program. The assessment should also include any possible concerns that may arise from trading, such as causing unreasonable harm to nearby land or beneficial water uses and if/how trading rules can be modified to avoid significant risks.
2. **Prepare reports and manage data:** Trades represent a change in location and timing of groundwater pumped within the framework of an established allocation. The GSA needs to track allocations and trades in order to manage the basin. It is unclear whether SGMA authorizes DWR to keep track of the same information about trading within a GSA or subbasin and therefore whether the GSA must report the full details of its own tracking information to DWR. The GSA's tracking needs to include the following information about each trade:
   - Buyer's and seller's annual allocation,
   - If seller's well is not metered, land and water use information needed to verify that sold amount was unused by the seller.
   - Status of allocation at time that trade is agreed to – amount used to date, amount carried over from previous year (if allowed),
   - Buyer's location (the wells/parcel whose allocation will be credited by the amount of the trade)
   - Seller's location (the wells/parcel whose allocation will be debited by the amount of the trade)
   - Details about the actual use (pumping) of the traded water – amount, location, timing
   - Status of buyer's and seller's allocation after the pumping of traded water.
3. Compliance with regulatory and grant requirements and providing data to DWR are addressed in the Data Management and Monitoring Method (MM-12). Data can be uploaded to the DWR system annually and progress on project implementation and monitoring can be provided in Annual Reports. If the project is associated with a GSP, the annual project summary should be provided in the Annual Reports, and a full project performance assessment should be provided in the 5-Year Assessment Report.

## Data Standards

Groundwater and water quality monitoring data should conform to the technical and reporting standards of the California Water Code §352 et seq.

Groundwater levels - Groundwater elevation measurements should be recorded relative to a consistent vertical datum.

Groundwater quality - Concentrations of groundwater quality constituents of concern should be compared to maximum contaminant levels available from the SWRCB.

## Key Protocols

The following protocols should be followed for required monitoring:

- DWR has not established installation, operation, maintenance, and accuracy standards or BMPs for wellhead meters for purposes of SGMA compliance (DWR, 2016). Some GSAs have established (or are developing) standards, and pumpers in adjudicated groundwater basins operate under rules set by the watermaster (see, for example, Chino Basin Watermaster, 2019).
- Standard groundwater level measurement and groundwater quality monitoring protocols are described in DWR's BMP 1 (DWR, 2016).
- Guidelines for establishing monitoring networks and resolving data gaps to reduce uncertainty are provided in DWR's BMP 2 Monitoring Networks and Identification of Data Gaps (DWR, 2016).
- Technical and reporting standards included in California Water Code (CWC) §352 *et seq*.

# Examples of Groundwater Trading Applications

## Chino Basin

**Location:** Los Angeles, Riverside, San Bernardino Counties

**Year:** Ongoing **-** Adjudication final in 1998

**Description and Relevance:**

Chino Basin is in the Santa Ana River Basin, primarily in San Bernardino County. The basin was over-pumped and degraded by long-term accumulation of nitrates and other salts from crop and dairy production. Negotiations to resolve issues and disputes began in the 1970s, resulting in a 1978 judgment, and culminating in an adjudication reached in 1998. Basin storage and safe yield of about 140,000 AF/year is split into three pools - Appropriative, Overlying Agricultural, and Non-agricultural Overlying. The adjudication allocates pumping to users within each of the pools.


**Figure MM14-2. Chino Basin Conjunctive Use Service Area Map** (Inland Empire Utilities Agency, 2021).

Pumping can be transferred between users within a pool or between pools, either temporarily or permanently. Transactions are privately negotiated and then must be reported to the Watermaster. Individual users may also accumulate carryover pumping credits subject to limits. Transactions must be approved by the Watermaster board. All extractions are metered or estimated to a required accuracy.

The Watermaster collects extensive water quality and groundwater level information as well as information on transfers and quantities pumped. Measurement and reporting requirements for the Basin are in the Basin Plan and the Watermaster's Rules and Regulations (Chino Basin Watermaster, 2019 and 2020). Other reports produced by the Watermaster, including those for SGMA compliance, can be found at the Watermaster's website.

**Links to Resources:**

For specific measurement requirements: http://www.cbwm.org/docs/OBMP%20Update/20201022%202020%20Optimum%20Basin%20Management%20Program%20Report%20FINAL.pdf

http://www.cbwm.org/docs/rulesregs/CBWM%20Rules%20and%20Regulations%20[2019].pdf

For list of reports: http://www.cbwm.org/pages/reports/

## Rosedale Rio-Bravo Water Storage District Water Accounting Platform

**Location:** Kern County

**Year:** 2020

**Description and Relevance:**

The Rosedale-Rio Bravo Water Storage District is working with the Environmental Defense Fund to generate an open-source water accounting platform for groundwater accounting across California. The tool provides an online platform for tracking, managing, and trading local groundwater allocations for improved management.

The platform is designed to:

- Create a better understanding of water demand and supplies, for Landowners to make informed decisions effectively and efficiently regarding water supply and land use.
- Utilize a satellite-based evapotranspiration model, called OpenET, to give landowners a past and present understanding of water demands on their specific parcels.
- Over the long term, develop the accounting platform into a trading platform, encouraging in-district water transfers.


**Figure MM14-3. Rosedale Rio-Bravo Water Storage District Accounting Platform Functions** (December 2020 Workshop#1).

At the time of preparing this description, Rosedale-Rio Bravo is testing the water accounting features of the platform but has not begun using it as the basis for groundwater trading.

**Links to Resources:** https://waterbudget.rrbwsd.com/ ; https://water.ca.gov/News/News-Releases/2021/May-21/Groundwater-Accounting-Platform-and-Data-Standards

## Fox Canyon Groundwater Management Agency Water Market

**Location:** Ventura County

**Year:** 2020-present

**Description and Relevance:**

The Fox Canyon groundwater market operates in a large area of Ventura County that includes over 55,000 acres of high-value agricultural land and 500 active agricultural wells. The basin is in overdraft and subject to seawater intrusion. Total annual pumping is capped, and an allocation to individual wells was implemented based on 2005-2014 historical use.

With assistance and some funding by The Nature Conservancy (TNC), the Groundwater Management Agency pursued developing a groundwater market. Participants ae required to meter well pumping. After years of development, the market exchange opened in March 2020. Still in a pilot phase, the market has only seen

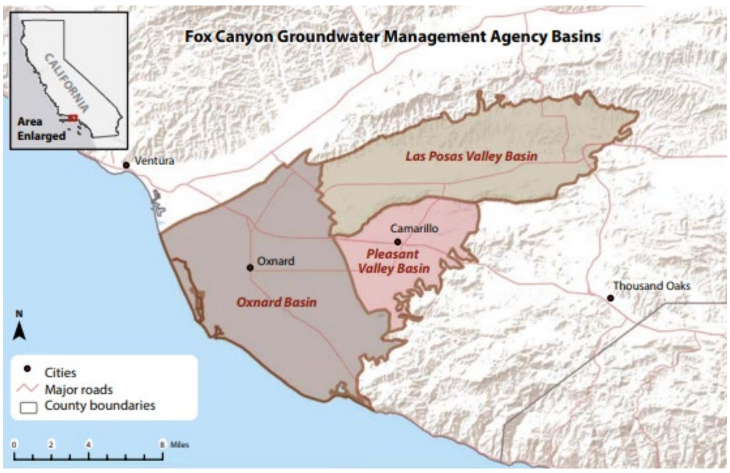


**Figure MM14-4. Fox Canyon Water Market Project Basin Map** (Heard et al, 2021).

limited trading – in 2020 about 58 acre-feet were traded. Reasons for relatively limited trading include initial allocations set high, availability of allocation variances in some cases, and ability of growers to pool allocations by grouping themselves into larger operations and trade within the operation. Nevertheless, TNC and its partners hope to demonstrate that market-based approaches can be a meaningful, fair, and sustainable way to achieve water conservation while engaging and supporting agricultural producers.

**Links to Resources:**

https://www.usda.gov/media/blog/2020/05/08/fox-canyon-water-market-market-based-tool-groundwater-conservation-goes-live

https://calag.ucanr.edu/archive/?type=pdf&article=ca.2021a0010

https://fcgma.org/allocation

## Murray-Darling Basin Authority Water Markets and Trading

**Location:** Australia

**Year:** Ongoing

**Description and Relevance:**

Groundwater trading markets under SGMA will be within groundwater subbasins and perhaps only within one or more GSAs in a subbasin. In contrast, the water market in the Murray-Darling Basin involves primarily surface water that can be traded across a large distance and between catchments within the larger basin. Therefore, concerns and outcomes in a large surface water trading market will differ from those in a smaller, groundwater-only market. Monitoring and measurement issues are also different between the two cases. However, the goals, implementation, and trading rules developed for the Murray-Darling Basin illustrate similar issues that local groundwater markets must consider.

Water in the Murray–Darling Basin can be bought and sold permanently or temporarily through their water trading program. Most of the water traded in the Murray–Darling Basin is surface water; however, some groundwater also trades. Water is traded on markets – within catchments, between catchments (where possible) or along river systems. The Murray-Darling trading allows water users to buy and sell water in response to their individual needs.

The price of water reflects supply and demand factors. It differs across regions and types of rights, and with time. Basin state and territory governments (Australia's equivalent to GSA and DWRs SGMA Program) are responsible for the management of the water trading and work to:

- determine water allocations
- develop policies and procedures for trade
- monitor water use
- develop water resource plans that set the rules for sharing water between users and the environment
- facilitate day-to-day trade operations such as trade applications and approvals.

Basin state governments set trading rules within their respective states. These rules need to be consistent with the Basin Plan and generally outline:

- where trade is allowed between different locations
- how trade transactions need to be conducted within the state.

This arrangement with state and territory governments provides a consistent water trading environment across the Basin, while still recognizing states and irrigation infrastructure operator's ability to restrict trade where necessary.

**Links to Resources:**

https://www.mdba.gov.au/water-management/managing-water/water-markets-trade

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