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A GROUNDWATER RECHARGE GUIDE

FOR VINEYARDS

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A GROUNDWATER RECHARGE GUIDE FOR VINEYARDS

A Groundwater Recharge Guide for Vineyards pairs Sustainable Conservation's expertise in on-farm groundwater recharge with the sustainable winegrape growing expertise of the California Sustainable Winegrowing Alliance (CSWA) to help winegrape growers respond to groundwater sustainability issues.

This guide provides you, the grower, with science-backed methods to evaluate recharge options for your vineyard and learn to implement recharge safely and sustainably. You will learn what Managed Aquifer Recharge (MAR) is, become familiar with the legal frameworks and natural resource considerations that shape recharge options for your farm, and get guidance on how to perform groundwater recharge. You will work through questions to outline a recharge plan for your vineyard, which you can then take to a Technical Service Provider in your area to develop a detailed Groundwater Recharge Plan.

Important note: This guide is intended to help farmers understand and outline possible MAR projects for their land but does not constitute legal advice or guarantee regulatory approval of your recharge project. MAR is a very site-specific activity and planning a MAR project can be complex. Once you have read the guide and completed the worksheet at the end, we recommend you utilize the technical expertise at Groundwater Sustainability Agencies (GSAs), irrigation districts, Resource Conservation Districts (RCDs), or University of California Cooperative Extension (UCCE) to plan your specific project. Information is current as of April 2026. While starting a project is an exciting endeavor, talk to your GSA or local regulatory authority before engaging in groundwater recharge activities.

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1. INTRODUCTION

What is Managed Aquifer Recharge?

Modern well technology allows us to extract more water more rapidly from underground reservoirs, or aquifers, than ever before. As a result, we have taken more water out of many of California's aquifers than can be replenished naturally. **Managed Aquifer Recharge (MAR)** is the intentional process of moving surface water underground into aquifers to help refill groundwater supplies.

Think of an aquifer as a battery. When we cannot plug into an outlet (surface water supply), we draw on battery power (groundwater). The battery needs to be recharged by connecting it to the power supply, just like groundwater needs to be recharged by receiving excess surface water when it is available.

Farms and homes within a basin draw water from the same aquifers. Farms tend to have bigger and deeper wells than individual homeowners and can pump greater volumes of water from deeper underground. This can cause a "cone of depression," a lowering of the water table that's shaped like an ice-cream cone centered on the well borehole (Figure 1). Shallower wells near that cone can go dry, especially in drought years. In California's most recent drought, thousands of rural residents lost access to water in this way.

MAR differs from typical irrigation because it requires applying large volumes of water over a relatively short period of time to push water down toward the groundwater aquifer. There are many ways to accomplish MAR. The simplest approach is to spread excess surface water on the ground or in a basin and allow it to infiltrate through the soil, sediment, and rock layers until it meets the water table. Sources of excess surface water can include high flood flows in a river, water released from a reservoir delivered through an irrigation canal, or stormwater runoff collected from the landscape.

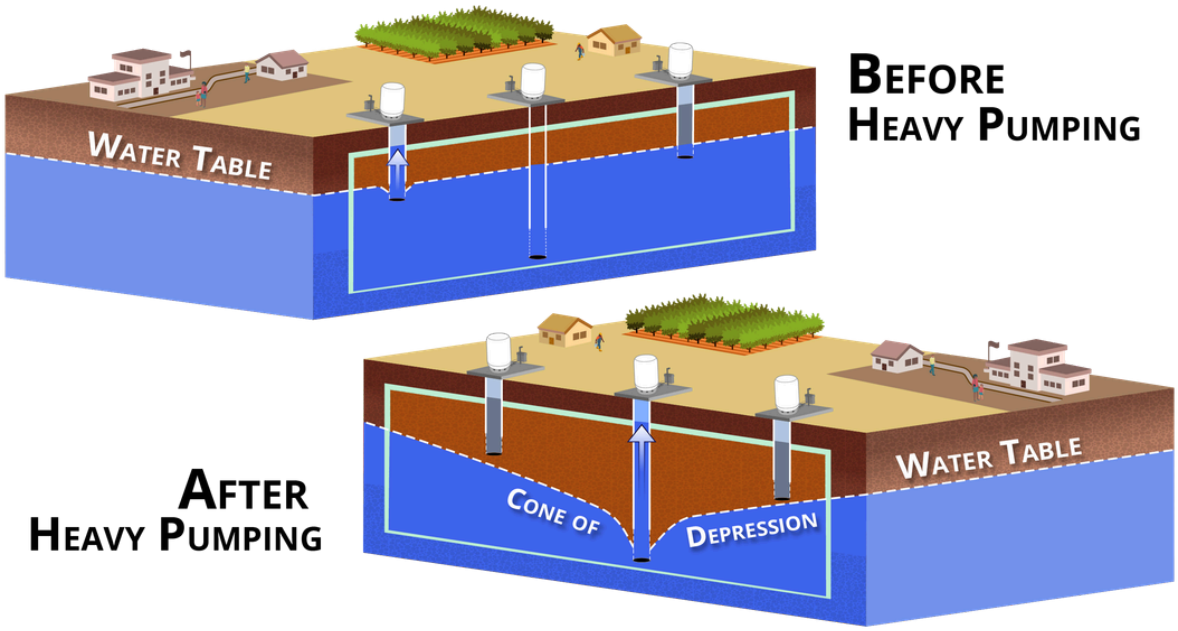


Fig 1. Simple visualization of how heavy groundwater pumping can draw down groundwater levels, forming a cone of depression that affects nearby wells.

Farms can be great places to spread water for recharge. When agricultural land is used for MAR, it's called **Ag-MAR** or **on-farm recharge (OFR)**. The suitability of a site for Ag-MAR depends on several factors, including:

- Soil and geologic layers that allow water to infiltrate and move downward toward the water table
- Access to a reliable surface water source and the infrastructure to move water to the site
- A crop that tolerates periodic soil saturation
- Farming practices that minimize the potential for water quality degradation.

Vineyards can be great candidates for Ag-MAR. Nitrate, a common groundwater contaminant from agricultural fertilizer use, is applied at lower rates in vineyards than in many other crops. This reduces the risk of nitrate contamination from recharge. In addition, excess water for recharge is most often available in winter, which aligns with the dormant season for vineyards, when vines can tolerate flooding more readily than during their active growing season.

Ag-MAR is easiest in areas that are relatively flat, and of course, not all vineyards are flat! Even vineyards on flat ground may have characteristics that limit Ag-MAR, such as heavy clay soils or hardpans that restrict water flow. In these cases, other MAR approaches may be more feasible in and around vineyards, including recharge basins or swales constructed in non-crop areas. Alternatively, a groundwater demand-reduction strategy—such as dry farming or in-lieu recharge, which substitutes a new surface water irrigation supply for pumped groundwater—may be the most effective way for a vineyard operator to address groundwater shortages.

This guide helps winegrape growers assess whether MAR is a good option for their vineyard and identify which method of MAR makes the most sense for their operation. The guide also provides practical information that growers need to practice MAR while protecting vine health and maintaining a sustainable business.

Why Do We Need MAR?

The Sustainable Groundwater Management Act (SGMA) was passed in 2014 in response to growing concern about groundwater depletion across California. Under drought conditions, wells were going dry across the state and leaving homes, businesses, and ag operations without a source of water. Many California groundwater basins are in a state of overdraft, meaning that more water is extracted from the aquifer than can be replenished naturally. SGMA mandates that groundwater extraction and replenishment be brought into balance. Groundwater budgets, just like any budget, can be brought into balance by decreasing demand or increasing supply. In many regions, local groundwater agencies are using MAR to augment groundwater supplies, as part of a broader plan to balance the budget in their local groundwater basin. Bringing groundwater levels up will not only help to satisfy the new groundwater regulation, it will also make groundwater supplies more sustainable in the future for rural communities, farms, and cities.

Groundwater does not only benefit people who depend on a well. In many areas, it provides water (referred to as "baseflow") to rivers, streams, and wetlands that support fish and wildlife. Groundwater, in addition to rain and snowmelt, is critical to keep many rivers, streams, and wetlands wet. If groundwater levels drop, these groundwater-dependent ecosystems may shrink or dry up for parts of the year, while recharge can help keep those ecosystems wetter for longer periods. Another method to preserve baseflow in fish-bearing streams is to use stored surface water for frost protection sprinklers rather than pumping groundwater or diverting winter surface water flows, which can dewater nearby streams during important winter migration periods.

During a flood, farms can be great places to spread excess water. Diverting water to farmlands can help reduce flood risk in developed areas, while also accomplishing groundwater recharge.

TIPS FOR NAVIGATING THE GUIDE

- To return to the Table of Contents, click the navy blue footer bar at the bottom of each page.
- If you are reading the guide in Adobe Acrobat, you can select alt+left arrow to return to where you were before clicking a link.
- If you are reading the guide in a web browser, you can select the browser back button to return to where you were before clicking the link.

Decision Support Question:

Which of these groundwater recharge benefits are important to me?

Whether you are interested in enhancing groundwater sustainability, reducing flood risk, supporting communities, supporting habitat, sustaining a farming economy, or some combination of these, where you recharge matters! For example, recharging near a groundwater-dependent community may help bolster water levels in that community's wells in a drought. You can target these objectives based on your location. Check out the map-based information below for these different objectives.

Groundwater Sustainability:

See the groundwater depths in your region for each year and season on the SGMA Data Viewer under *Groundwater Levels.*

Flood Risk:

See areas downstream or near you that face flood risk within FEMA's effective 100-year floodplain in the SGMA Data Viewer under *Reference Layers*.

Groundwater-Dependent Communities:

The Dry Domestic Well Susceptibility Dashboard displays the densities of susceptible dry wells across the state.

Groundwater-Dependent Habitat:

The Natural Communities Commonly Associated with Groundwater data can serve as a starting point to identifying groundwater-dependent ecosystems in your area.

While there may be other factors that should be evaluated to determine if recharging on your field can provide these benefits, this is a good first step!

Record your thoughts on the Groundwater Recharge Worksheet for Vineyards (p. 37)*!*

2. PREPARING FOR MAR

Legal and Regulatory Framework

The **Sustainable Groundwater Management Act (SGMA)** has brought new scrutiny to groundwater use in California since it passed in 2014. SGMA mandated a new system of groundwater management based on local governance by newly formed **Groundwater Sustainability Agencies (GSAs)**. Each GSA is responsible for developing and implementing a **Groundwater Sustainability Plan (GSP)** to bring the groundwater budget into balance.

Not all areas of California have groundwater basins (non-basin areas), and some areas already have groundwater regulation mandated by court orders (adjudicated basins). Basins subject to SGMA regulation were assigned a priority rating based on factors including population, number of wells, irrigated acreage, and groundwater conditions in the basin (2019 Basin Prioritization report, CA Department of Water Resources). High- and medium-priority basins were required to form GSAs by 2021 and to develop and implement GSPs by 2024, while low- and very low priority basins were given the option to prepare GSPs. As a result of variations in groundwater governance, different winegrape-growing regions face different regulatory constraints on groundwater use based on where they are located. Even neighboring areas may have very different sustainability plans and methods for implementation. Levels of public awareness of groundwater rules also vary by region, due to the variety of regulatory structures and implementation schedules applicable in different areas.

In many basins, local GSAs, irrigation districts, or other groundwater authorities are using MAR, including Ag-MAR, as a part of their groundwater management plans. They may offer incentives to growers to conduct Ag-MAR.

To consider MAR, you first need a source of surface water that is legally available to you. If your goal is to later pump the recharged water out for irrigation or other uses, you must have the legal right to store that water underground and use it later.

It is easiest for a grower to operate under the umbrella of a water or irrigation district's water rights. If your vineyard is within an irrigation district, start there. Talk with district staff to understand how they are working with growers who are interested in MAR. Although a streamlined permitting process through the State Water Board exists for groundwater recharge, obtaining a permit as an individual grower can be costly and challenging. A district is much more likely to obtain a recharge permit, especially when recharge is identified as a priority project in the local Groundwater Sustainability Plan (GSP).

If you are not in a water district, you may be able to access water from a neighboring district, if there's a way to physically move the water and if that district is willing to help with recharge projects outside its jurisdiction. Other

sources of water available to those outside of a water district are discussed below.

Vineyards also exist in areas that are not subject to SGMA and therefore do not have a GSA. Groundwater in non-SGMA basins, or in non-basin areas, may be governed differently. For example, in "adjudicated basins," groundwater is managed according to a court-approved plan. If your vineyard is in an adjudicated basin, talk to your watermaster or other court-appointed authorities to find out whether Ag-MAR is supported by the agency and whether there are any incentives for recharge. To find the groundwater agency that covers your farm, see the box below.

Decision Support Question:

Am I in a GSA, adjudicated basin, or non-basin area? Where can I find information about the GSP or other local groundwater governance?

Follow the steps below to find out if you are in a GSA or adjudicated area.

1. Go to the SGMA Data Viewer website.
2. Enter your address or simply zoom in to your region.
3. Under **Reference Layers**, select **Groundwater Sustainability Agencies** and **Adjudicated Areas**.
    a. Toggle the **GSAs** layer off to view the **Adjudicated Areas** layer.
4. Click on the GSA or adjudicated area that covers your field in the map. A table will open at the bottom of the screen with information on your GSA or adjudicated area.

Record your answers on the ***Groundwater Recharge Worksheet for Vineyards*** *(p. 37)!*

Water Sources

Water delivered from a water or irrigation district using existing infrastructure is the simplest way to get water for recharge. So how can a grower located outside of a water district participate in MAR?

You may be able to use floodwater during a flood emergency. In 2023, Water Code 1242.1 was established, which allows the diversion of floodwater for the purpose of recharging groundwater aquifers without obtaining a water right permit.

Certain conditions apply:

- A local agency has declared a flood emergency.
- Diversion pumps may be permanent or temporary, and a fish screen is required.
- The diverter must have legal control of both the diversion pump and pipeline infrastructure and the land where the water will be applied.
- The land where the water is applied must meet certain conditions for water quality protection.
- The diverter must report their intent to divert water to the State Water Board before the diversion and must report the actual amount of water diverted afterward.

It is important to note that Water Code 1242.1 allows recharge without a water right and without a permit, but it does not create a right for the recharger to extract the water later. In other words, if you recharge water using this authority, it does not become "yours". You are still subject to any local groundwater pumping allocations that apply without direct benefit to your farm's groundwater account.

For the most current details about using flood flows for recharge, visit the State Water Board's website. This is an evolving area of legislation and requirements may change.

Other water sources also have limitations for groundwater recharge. **The methods described below, similar to the flood emergency water described above, do not give the recharger the right to pump recharged groundwater for irrigation or other uses later,** but may help with local groundwater levels. Any local groundwater pumping allocations still apply without direct benefit to your farm's groundwater account. Other incentives may be available locally; see **Section 5**.

- **Overland flow –** Water that runs off the landscape during storm events may be slowed down and allowed to sink into the ground. Various overland flow capture techniques are described in **Section 4: Alternative MAR** and groundwater demand reduction methods and many are commonly used to prevent erosion and sediment loss on sloping hillsides. Recharge by this method does not create a right for later extraction of the water, and a grower must be careful not to impair the water rights of downstream users by preventing overland flows from entering a stream.

- **In-lieu recharge –** When a surface water source is used for irrigation instead of pumped groundwater, demands on the aquifer are reduced. While this is a demand-reduction method rather than a direct recharge method, it can help groundwater levels rebound.

- **Winery process water –** Discharge from winery operations may be a potential source of water for recharge, though the quantity of water may be insufficient for recharge and more suitable for irrigation. In either case, you would need a permit for land application of winery discharge water from the Regional Water Quality Control Board that covers your vineyard and winery. The permitting process for applying winery process water to land requires an analysis of the process water quality and may require nutrient and salt management plans. Substituting winery process water for groundwater pumping may be considered in-lieu recharge.

- **Recycled water –** If you happen to have a connection to recycled water (a so-called "purple pipe"), treated wastewater may be a source of water for recharge. Local and state regulations on the use of recycled water would need to be followed, and you should consider the quality of the water to be used. As with winery process water, quantities may not be sufficient for recharge but more suitable for irrigation. Substituting recycled water for groundwater pumping may be considered in-lieu recharge.

Decision Support Question:

What water source(s) might be available to me for MAR?

Winter recharge water delivered by your water or irrigation district is the simplest option. If your vineyard is within a water or irrigation district, start by asking your district if water may be made available for recharge at your location.

Water diverted from rivers, streams, or canals during flooding events may be available under Water Code 1242.1. Your district, GSA or watermaster may be able to help you understand the process for using emergency flood water for recharge.

Surface water sources including overland runoff, winery process water, or recycled water might be usable for groundwater recharge. Alternatively, those sources could be used for irrigation **to achieve in-lieu recharge**.

Record your answers on the ***Groundwater Recharge Worksheet for Vineyards*** *(p. 37)!*

Site Considerations

MAR differs from typical irrigation because it requires applying large volumes of water over a relatively short period of time to move water down through the soil profile toward the groundwater aquifer. In a typical Ag-MAR scenario, large volumes of excess surface water flow are delivered to vineyards during their winter dormant season. **The target for total volumes of water applied will vary by site,** depending on factors such as the infrastructure available to deliver and spread the water on the field and the rate at which water can infiltrate the soil and percolate through underlying geologic sediments to the water table. An initial target might be to apply 1 to 1.5 acre-feet per acre during a recharge event that might last 3 to 7 days. This target can be adjusted based on your vineyard's specific characteristics. See **Vineyard health and MAR** for specific guidelines for choosing water application targets for your site.

Capacity to deliver and spread water

Flood irrigation for MAR requires significantly more water per day than driplines, micro-sprinklers, or solid-set sprinklers can apply, even when they are turned on for extended periods. Vineyard farmers who do not have the existing infrastructure to conduct flood irrigation should consider whether it is feasible to retrofit or bypass drip or sprinkler systems with temporary or permanent pumps and pipes to increase water delivery to the vineyard for MAR. Furthermore, vineyards may need temporary adjustments to grading, such as low earthen berms, to spread recharge water evenly across the field- some strategies for use in existing vineyards are explored in **Section 3, Preparing vineyards for recharge.** Refer to **Section 5** for cost considerations.

> Some pilot studies are investigating whether pressurized systems can effectively recharge groundwater — see **"Case Study: On-Farm Recharge Pilots in Sonoma County."**

The water for recharge might come through a farm parcel turnout connected to an irrigation district canal system, or you might use **a diesel pump to divert excess floodwater** from a river, creek, or stream. Of course, you must have access to available **excess surface flows of water** during vineyard winter dormancy, accompanied by the appropriate water rights (refer to **Section 2, Legal and Regulatory Framework**). The transport of this water from its source to the recharge site can be done through permanent or temporary pipelines.

Water district turnouts can deliver 2.5 acre-feet per day through a turnout rated at 5 cubic feet per second (CFS), up to approximately 10 acre-feet per day through a 20 CFS turnout. Turnouts are typically rated at 5, 10, 15, or 20 CFS.

Diesel pumps can deliver anywhere from several hundred to several thousand gallons per minute (GPM). The flow rate is primarily dependent on the pump size and engine horsepower. The pump is chosen to meet the water application requirements of the field, and delivery pipelines are sized to match. For comparison with the capacity of the canal turnouts discussed above, a 1,000-GPM pump will deliver approximately 4.4 acre-feet of water per day.

Decision Support Question:
What infrastructure do I have in the field?

Recharge infrastructure:

- Consider how water can be delivered to your vineyard. If turnouts or pumps and pipelines are not in place, would it be feasible to install temporary or permanent equipment?
- If flood irrigation is not currently used on the vineyard, consider whether it is feasible to retrofit the field for flooding, including temporary grading adjustments or berms and water distribution pipelines or ditches.

Record your answers on the ***Groundwater Recharge Worksheet*** *for* ***Vineyards*** *(p. 37)!*

Soils and Geologic Layers

The characteristics of your soil at the surface and deeper below ground help determine how much water you can apply and how quickly it will infiltrate and percolate to the aquifer.

Soil type: Sandy soils are coarse and allow water to move quickly through the soil. This protects crop health by preventing water from sitting in the soil for too long and waterlogging the roots. On the other hand, finer soils with more clay and silt will drain more slowly. The good news is you can likely still recharge on these soils—you will just have to apply less water.

Other factors: Recharge suitability is also determined by the slope of the fields, how prone the soil is to erosion, and the salt content (salinity) of your soil. Deeper subsurface conditions, such as a high water table or the presence of clay layers that restrict the flow of water, can further limit a field's ability to infiltrate and store water.

If you want to determine how much water to apply to your land—or even whether recharge is right for you—there are statewide datasets that provide estimates of site suitability. These resources are discussed on the next page.

Keep in mind that these are regional datasets that may not be accurate at the field scale. **Your own experience with past flooding events and knowledge of your field is often a better indication of your site's suitability for recharge.** For example, you might have a small portion of a field where an old creek channel runs through that percolates water easily, even if the entire field is rated poorly for recharge suitability. Technical assistance providers with local knowledge of groundwater conditions can offer more customized support to evaluate your site's characteristics and help ensure that your recharge water application is done safely and protects your vineyard. Some organizations to contact are listed in **Appendix A**.

Decision Support Question:

What is my site's suitability for recharge?

For Central Valley growers:
The Recharge Suitability Index (RSI) can tell you how suitable your site is for recharge based on the ability of your soils to infiltrate groundwater, as well as deeper subsurface conditions such as depth to bedrock, existing groundwater, and restrictive layers. The RSI is only available for land within the Central Valley.

To view your vineyard's Recharge Suitability rating:

1. Go to the *GRAT Viewer website*.
2. Enter your address or simply zoom in to your field.
3. Turn on the ***Land IQ Groundwater Recharge Suitability*** layer.

For growers beyond the Central Valley:

The **Soil Agricultural Groundwater Banking Index (SAGBI)** is available for more of California's growing regions in addition to the Central Valley. It can tell you how suitable your site is for recharge based on five factors: (1) the ability of the soil to transmit water below the root zone, (2) how fast the water will drain from the crop's root zone, (3) soil salinity, (4) topography, and (5) soil surface conditions.

To view your vineyard's Recharge Suitability rating:

4. Go to the ***SAGBI website***.
5. Go to ***Map Settings*** and enter your address or simply zoom in to your field.

Is your vineyard not covered by RSI or SAGBI? Check out the **NRCS Web Soil Survey**, which provides information on your soil that can help you assess your field's potential for recharge. See Appendix C for a quick guide to finding soil properties related to recharge.

Record your answers on the ***Groundwater Recharge Worksheet for Vineyards*** *(p. 37)!*

Water Quality

Growers in California are used to considering the impacts of their day-to-day operations on surface water quality. The effects of land management practices tend to appear fairly immediately in surface water. In contrast, the impacts of farm management decisions may not appear in groundwater quality measurements for years or decades.

For example, nitrogen fertilizer applied to a sloping vineyard before a major storm might be carried with eroding surface soil into a nearby stream, which may experience an algal bloom soon after that harms aquatic ecosystems. In contrast, nitrogen fertilizer applied over many growing seasons can accumulate underground and take years to reach the groundwater aquifer. Even if a grower reduces fertilizer applications once excess nitrate is found in a well, it will likely take years to diminish or dilute the excess nitrogen already stored in the soil and sediment layers.

For a water pollution problem to exist, there must be a source of the pollutant and a pathway for the pollutant to enter the receiving water. Pollutants that dissolve in water (water-soluble) are carried into an aquifer with water percolating from the soil surface down through underlying sediment layers in a process known as leaching. The pathway of water from the soil surface to a well can be very complicated, making it nearly impossible to trace exactly where a pollutant in well water originated.

Water-soluble agricultural materials that are commonly associated with groundwater contamination in basins dominated by agricultural land uses include nitrogen in the nitrate form, salts originating from fertilizers, and certain pesticides that do not "stick" to soil particles or that have long half-lives. Other agricultural pollutants, like pathogens from compost or manure, are less commonly found in groundwater than in surface water. There are also "emerging contaminants" like Per- and Polyfluoroalkyl Substances (PFAS), which can be found in biosolids or recycled water that may be applied to cropland. PFAS's behavior in water and soil is not well understood, and water quality guidelines for health and safety are not yet established.

While it may be difficult to correlate a pollutant in a well directly to a source on a farm, we can identify the sources of water pollutants on each farm and evaluate the likelihood of losing those pollutants to groundwater. Use the acronym "**ACT**" to think about different best management practices that **A**void, **C**ontrol, or **T**rap sources of water pollution on the farm.

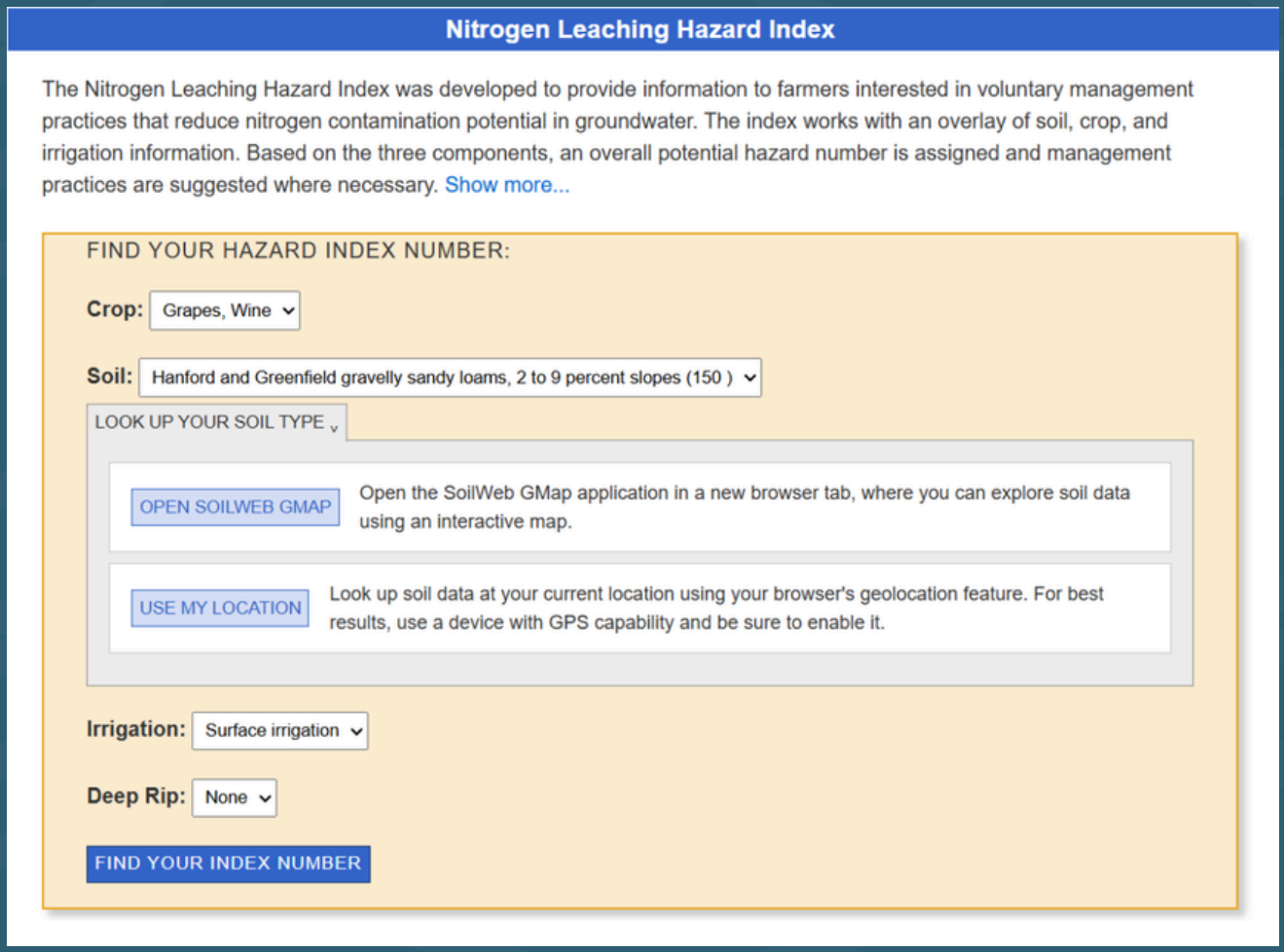
For the greatest efficiency in pollution prevention, prioritize Avoid practices first, then Control practices, and Trap practices last.

Avoid: Eliminate or use less of potential pollutants	**Control:** Retain potential pollutants in the agricultural field to eliminate loss to the environment	**Trap:** Collect potential pollutants before they reach water bodies or groundwater
• **Nutrient Management:** "4R" strategies (**R**ight source, **R**ight time, **R**ight rate, and **R**ight place) to reduce soil nitrate available for leaching • **Integrated Pest Management:** minimize use of highly leachable pesticides	• **Irrigation water management:** strategies like water budgeting and soil moisture monitoring to keep irrigation water in the root zone • **Cover crops:** take up excess nutrients during the wet season to prevent leaching • **Targeted application:** using nutrients and pesticides in targeted areas rather than across an entire field	• Tailwater ponds • Sediment basins • Filter strips and vegetated ditches • Treatment wetlands • Tile drainage water management • Denitrifying bioreactors • Denitrifying saturated buffers *For links to NRCS practice standards on these practices, see the Table of Resources under Water quality.*

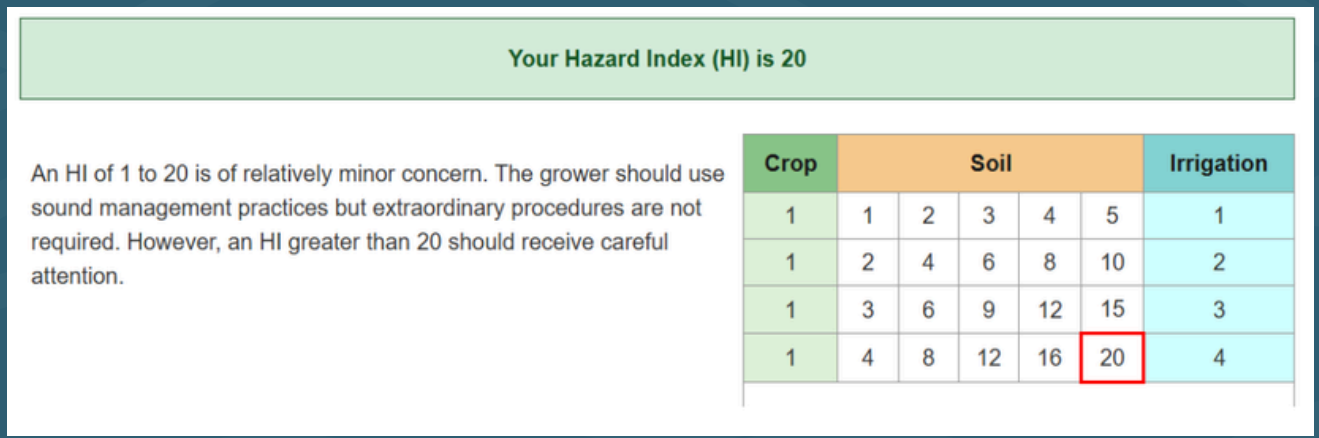
Decision Support Question:

Do I have hazards to water quality on my vineyard? If so, what Best Management Practices might I implement to mitigate?

Nitrate: Look up your farm's risk of nitrate leaching using the **Nitrate Leaching Hazard Index tool**. Input your crop, soil type (there is a lookup function if you don't know it), and choose "Surface Irrigation" to approximate recharge flooding events. Choose a deep ripped option based on your field.



Then click “Find your index number.” You’ll get a report and an explanation of the hazard index specific to your field.

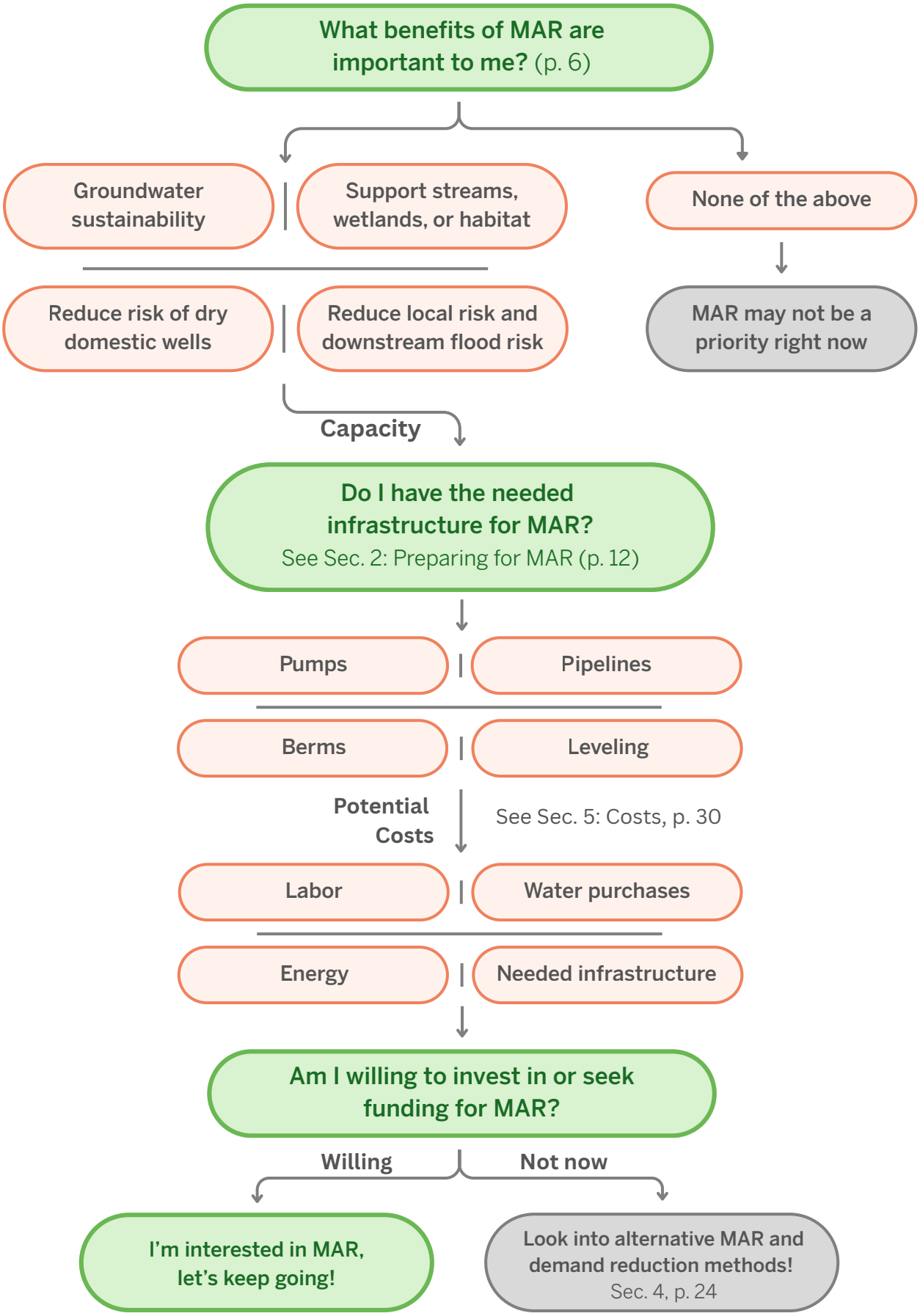


Pesticides: The State Water Resources Control Board, which regulates water quality in California, has recognized several pesticides as highly likely to contaminate groundwater by leaching. Groundwater recharge may not be performed within 6 months of using these materials, many of which are herbicides. This "No Recharge List" appears in **Appendix D**. Compare this list with your Pesticide Use Reports.

Planning Best Management Practices to protect water quality: If you suspect you may have a hazard to water quality on your vineyard, you can reach out to Technical Service Providers (see Appendix A) for help in deciding which BMP's might work for you to protect water quality. Folks with local expertise can be found with your local Resource Conservation District, the USDA Natural Resources Conservation Service, your water quality coalition or Groundwater Sustainability Agency, or private Pest Control Advisors (PCAs) or Certified Crop Advisors (CCAs).

Record your answers on the ***Groundwater Recharge Worksheet for Vineyards*** (p. 37)*!*

Should I do MAR?



Record your answers on the ***Groundwater Recharge Worksheet for Vineyards*** (p. 37)!

3. MAR IN VINEYARDS

Vineyards can be great places to practice MAR because of their relatively lower use of nitrogen fertilizers, and the coincidence of recharge water availability with the winter dormant season for vineyards. Additional factors to evaluate when considering whether a particular vineyard is a good MAR location include considerations for crop health, field setup and maintenance, and water management during a MAR operation.

Vineyard Health and MAR

Vines with known root or trunk disease or soil-borne pest problems should not be flooded. MAR may stress the vines and make disease pressure worse, or the wet conditions may promote the growth of fungal diseases. Even if there is no current evidence of disease, the best practice is to avoid MAR applications on rootstocks with low or no resistance to common root rot or crown rot diseases to prevent plant health issues.

Consider your rootstock's tolerance of flooding in combination with the soil type in the vineyard (References on rootstock selection are listed in the **Table of Resources** at the end of this guide). Heavier clay soils or soils with a restrictive clay layer stay wetter for longer after recharge, which has a greater impact on root aeration than lighter, sandier soils that drain more quickly. Refer to **Section 2, Site Considerations - Soils and geologic layers**, to assess your soil.

Common root diseases and pests	Common trunk diseases
• Phytophthora root & crown rot diseases • Blackfoot (causes root & trunk necrosis in young vines) • Petri disease (young vine decline) • Armillaria root rot (Also known as Oak rot) • Nematodes can transmit viruses like fanleaf virus when feeding on vine roots	• Botryosphaeria • Eutypa dieback • Phomopsis dieback • Esca (black measles)

Planning How Much MAR and When

The ideal time for MAR is during the dormant season when crop production is finished and vines are completely defoliated. Winter dormancy time for winegrapes occurs from November through March in California and is largely influenced by regional climate and rootstock-scion wood selections. It is best to conduct MAR during vineyard winter dormancy, while the vine's biological functions are minimized, and avoid MAR during the growing season. When the vine is actively transpiring and growing, limited oxygen availability to the roots in saturated soil conditions can impact plant health.

Applications of recharge water can be planned based on your soil type. Table 1 uses a model developed by the California Department of Water Resources (Flores-López et al. (2025)) to calculate the amount and frequency of water application for recharge based on soil texture. The data shown is specific to winegrape crops. Water is applied for five consecutive days, limiting the applied amount to keep the root zone saturation below 75% to protect crop health. These five days are followed by several days of no water application to allow time for the soil to dry before applying water again. Table 1 displays the suggested water application amounts and drydown periods for different soil textures, turnout sizes, and seasons. A grower can extend the drydown period to do cultural operations in the vineyard. To minimize nitrate leaching, avoid applying recharge water after a nitrogen fertilizer application. Please note that these recommendations are based on a model; you will need to monitor recharge events in your field and manage water applications based on site conditions.

Decision Support Question:

How can I protect crop health during recharge, and apply the right amount of water at the right time?

Are there pests or diseases present in the vineyard that might get worse if I flood the field?

How flood-tolerant is my vineyard's rootstock? Use the rootstock references provided in the **Table of Resources**.

How long should my flooding events and drydown periods be, based on **Table 1** (next page)?

*Record your answers on the **Groundwater Recharge Worksheet for Vineyards** (p. 37)!*

Table 1. Suggested Recharge Rates and Timing for Winegrapes, with 5 days of flooding

Soil type	SAGBI rating	Turnout size (cfs)	**Rate of water application** (acre-inches per acre-day)	**Minimum drydown period** (days) **Oct - Dec**	**Minimum drydown period** (days) **Jan - Mar**
Sand	Excellent	20	24	10	10
Sand	Excellent	15	18	10	10
Sand	Excellent	10	12	9	9
Sand	Excellent	5	6	9	9
Loamy Sand	Good	20	24	24	21
Loamy Sand	Good	15	18	24	21
Loamy Sand	Good	10	12	24	21
Loamy Sand	Good	5	6	23	20
Sandy Loam	Mod Good	5	5.7	42	33
Sandy Clay Loam	Mod Poor	5	4.5	41	33
Clay Loam	Poor	5	4.4	27	23
Sandy Clay	Very Poor	5	3.8	29	24

Preparing Vineyards for Recharge

MAR requires moving large amounts of water to the vineyard and spreading it on the field. Refer to **Section 2, Site Considerations - Capacity to deliver and spread water**, to evaluate your water source and the equipment and infrastructure available to move the water from the source to your vineyard.

To apply recharge water as uniformly as possible to the field, or to direct water to a section of the field best suited for recharge, the slope and drainage layout may need adjustment. Locate where water enters the field and identify how it will flow according to the slope of the ground. Decide what your target daily application rate of recharge water will be, based on the limits of your water delivery system, the **Suggested Recharge Timing for Winegrapes** guidelines in **Table 1** above, and how deep the water can be on the vineyard floor. If the vine rows are bermed, keep water levels below the top of the berms. If there are no berms, keep the water below the rootstock-scion graft.

Your field layout and drainage can be temporarily altered for MAR with some simple techniques and strategies. Choose what might work for you based on the soil's ability to infiltrate water, your knowledge of how the site drains, and your comfort level with flooding the vines.

1. **Furrow or alternate-row irrigation** may be appropriate if you have access to a limited amount of water or if you want to minimize waterlogging due to heavy soils or the timing of recharge after leaf out. Small earthen check dams in the furrows made with a shovel can slow water movement, promote infiltration, and help prevent runoff at the bottom of the field.

2. **Low berms in the middles,** parallel to the vine rows, can help contain water in certain parts of the vineyard. This can be especially useful if there is a zone within the field that has better infiltration characteristics and you want to concentrate recharge water in that area.

3. **Temporary berms across the middles,** especially where vines are on berms, can help slow recharge water or concentrate it, allowing greater time for infiltration.

4. **Larger berms around the edges of the vineyard** will help contain water on the field if larger volumes of recharge water are expected.

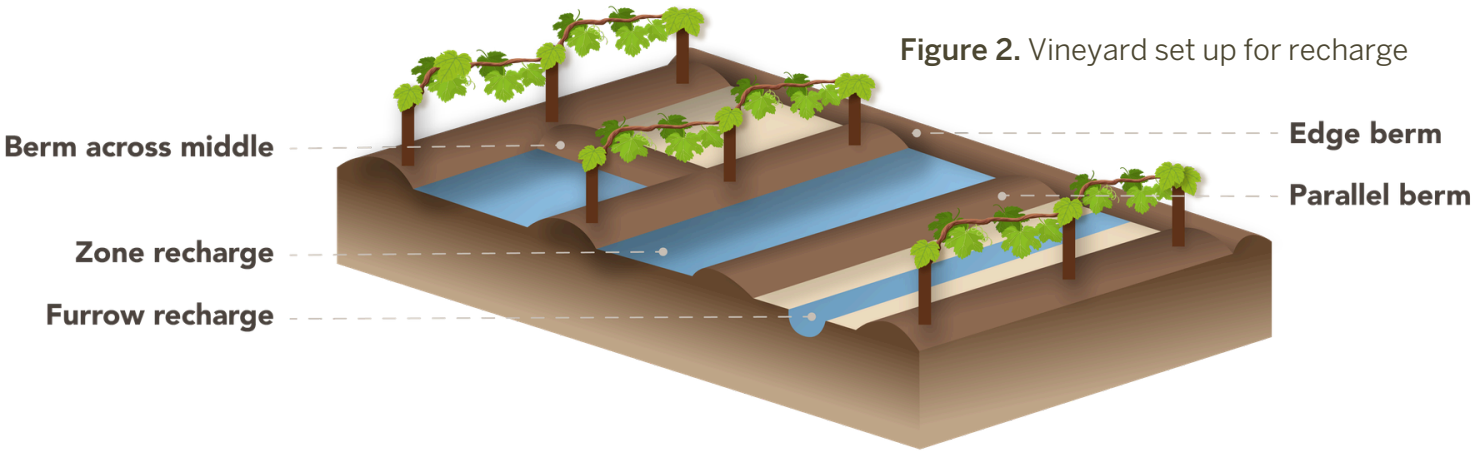


Figure 2. Vineyard set up for recharge

Soil texture with high sand content allows water to move relatively quickly through the soil profile. However, for soils with more clay content, infiltration may be slower and intermittent low berms perpendicular to the direction of water flow may be helpful. These cross-berms will build a shallow head of water in a smaller area, slowing water advance across the field and promoting infiltration. A larger 1- to 3-foot outer perimeter berm may be needed to safely contain recharge water on the field.

Cover crops or vegetation on the vineyard floor can improve infiltration rates, prevent surface soil sealing, and reduce erosion. Most cover crop species can withstand short periods of flooding, such as the 3-7 days recommended for MAR. You don't need to mow or disc your cover crops before recharging unless the cover crop is greater than 1 to 2 feet tall, which can impact water movement. Many different types of cover crops can be used to facilitate recharge, including those that also support pollinators, fix nitrogen, build soil carbon, and help alleviate compaction. A wealth of information specific to cover cropping in California vineyards can be found on the web; see the **Table of Resources** at the end of this document for links.

A field where a vineyard has been removed can be a great candidate for recharge. The field still needs a water supply and may need earthwork to help spread and hold recharge water, but concerns for crop health don't apply. In fact, extending the fallow period before replanting and conducting recharge on the field in the meantime can benefit the future vineyard by interrupting pest cycles and reducing soil pathogens, especially if you plan to recycle the vineyard removal biomass into the soil. Pairing recharge with practices like cover cropping to improve infiltration and soil health can maximize benefits.

Managing the Recharge Event

The farmer must coordinate the delivery time of water, typically during the plant dormancy or wintertime, with their local irrigation district manager. Otherwise, they must coordinate the diversion of floodwater, in accordance with Water Code 1242.1 regulations mentioned above, from a stream, lake, or river to a targeted field for MAR. It is critically important that the fields be prepped and ready at the beginning of the rainy season because you may need to act very quickly to take water once it is available.

Think of Ag-MAR simply as a flood irrigation during the off-season. Experienced irrigators will be needed to manage the water on the field to ensure even spreading and to troubleshoot any problems, such as a broken berm or runoff at the bottom of the field. Irrigators can judge when the water should be turned off to prevent losses. Techniques like surge irrigation can be used to improve infiltration efficiency by reducing pooling of water and increasing infiltration in soils with more clay content.

The amount of water delivered to the field must be measured. A flow meter is ideal, but water quantities can also be calculated from the flow capacity of a field

turnout or pump, typically in gallons per minute (GPM) or cubic feet per second (CFS), and the length of time that the pump or the turnout is flowing. The grower or the irrigators must be responsible for recording the "water on" and "water off" times, as well as the flow meter readings or the flow rate of the water inlet. If you are working with an irrigation district, ask about specific requirements for record-keeping. An example data sheet is provided in **Appendix B**.

A typical recommendation is that recharge water only stays on the field for 3 to 7 days to avoid long-term soil saturation and potential damage to crop roots (See **Table 1** above). Use your observations of the depth of water in the field and the time it takes to fully infiltrate after the water is turned off to modify your MAR applications to prevent damage to the crop or field, and to plan for future recharge efforts. A field can be recharged more than once during the winter season if water is available. The field should be allowed to dry down between MAR events, which also allows cultural practices like pruning or mowing to take place. See **Table 1** above for guidelines on MAR application rates, flood duration and dry-down periods for your soil type.

Decision Support Question:

What is my target MAR application and timing? Do I need to modify my field's layout to control MAR water? How will I measure water applied for MAR?

Water application rate (acre-inches per acre per day, from Table 1):

_____

Maximum allowable depth of water in the vineyard (inches):

_____

I will measure applied water using:

☐ flow meter or ☐ other method _____

To conduct MAR, my field may need:

A measuring device, flow meter or other type: _____

☐ Berms around the edges of the field

☐ Berms to contain water to a certain area of the field

☐ Berms across the middles

☐ Alternate-row flooding

*Record your answers on the **Groundwater Recharge Worksheet for Vineyards** (p. 37)!*

4. ALTERNATIVE MAR AND GROUNDWATER DEMAND REDUCTION METHODS

If Ag-MAR is not feasible for your vineyard due to slope or other factors, you can explore other methods of MAR that might work in or around your vineyard. Alternatively, you can consider ways to shrink your operation's use of groundwater ("demand management") to address groundwater scarcity.

Groundwater recharge basins – Landowners can make their own basins by digging depressions in non-cropped areas of the farm. With a basin, you don't have to restrict recharge to the vineyard's dormancy period or time MAR to accommodate field operations. Basins are well-suited to take emergency flood flows on short notice in the winter and can accept water year-round when it is available.

Key considerations for siting and designing on-farm basins include soil infiltration rates, water availability to fill the basin (both water rights and infrastructure conveyance), safety, permit needs, and local regulations like mosquito control. Costs are a key factor, not only the cost of construction but the costs of maintenance and water to fill the basin. The Natural Resources Conservation Service has an interim practice standard for Groundwater Recharge Basin or Trench, which outlines design parameters for on-farm recharge basins.

Landowners interested in providing wildlife habitat can design basins with features such as relaxed side slopes and variable bottom depths to provide a range of habitat needs. The guide "Building multi-benefit recharge basins" includes design considerations for enhancing shorebird, waterfowl, and pollinator habitat.

Subsurface "reverse tile drain" recharge – A perforated pipe installed below the crop root zone is used to apply excess surface water to recharge depleted aquifers. These systems don't saturate the root zone, reducing concerns about soilborne disease and fertilizer or pesticide losses, and allowing recharge during active crop growth. The systems can be expensive and must be installed before a vineyard is planted.

Upslope swales and berms on non-cropped adjacent land – Swales (shallow depressions in the ground that briefly hold or convey water in rain events) can be used to slow overland flow and infiltrate it into the ground. Swales and berms (raised banks on the downhill side of swales—usually made from the material dug from the swale) can be created on topographic contours on steeper terrain, which helps reduce erosion and pollutant runoff. For design considerations, refer to the NRCS Conservation Practice Standard for Terraces.

Vineyard swale rewilding – Natural swales in vineyards may be waterlogged and less productive than other parts of the vineyard, so it may make sense to remove the vines and repurpose the area to alternative uses, such as natural recharge areas. Native vegetation, pollinator species, or cover crops can be planted to improve habitat functions and improve biodiversity that may be beneficial for the vineyard. See the **Table of Resources** for links to information on cover crop seed selection and management.

Flow-through basins (FTBs) – FTBs are small basins or floodplains constructed adjacent to flashy creeks and rivers that can serve to reduce local flood risk, improve habitat, and recharge groundwater. Ideally, FTBs are gravity-fed during storm events and remain unirrigated during the dry season.

Vineyard removal or fallow fields – When vineyards are ready for removal, growers can opt to allow the fields to remain fallow for a period of time. This allows for regeneration of the soil, reduction in diseases or pests, and reduced water demand. Depending on site variables, fields in transition could serve as recharge locations during the fallow period.

In-lieu recharge (ILR) – ILR is when surface water is used for irrigation instead of groundwater. "New" sources of surface water might include an irrigation reservoir filled with surface runoff, winery process water, or recycled water where it is available. See **Section 2, Water Sources**.

Dry farming – Many grapes are dry farmed or partially dry farmed. Techniques include lower-density plantings and deficit irrigation, as well as fully non-irrigated vineyards. The guide "Dry Farming in California Vineyards: A Guide for Winegrape Growers" explores considerations and techniques for establishing a dry-farmed vineyard or converting an existing vineyard to dry farming, and is available from the California Sustainable Winegrowing Alliance.

Decision Support Question:

Are any of these methods better suited to my operation than flooding in the vineyard?

Alternative MAR technique	Works best when:
Groundwater recharge basin	Vineyards lack infrastructure for flooding, or primary water source is emergency flood flow, or recharge water is available when vineyard is not dormant
Subsurface recharge	Recharge water is only available during the growing season, and system can be installed before vineyard is planted
Upslope swale and berm	Vineyard is on a steeper slope, and non-cropped land is available
Vineyard swale rewilding	Low-lying areas of the vineyard are unproductive or hard to farm
Flow-through basin (FTB)	Low-lying areas adjacent to streams that regularly flood during storm events
Fallow field recharge	Vineyards are in transition (vines have been pulled out) and vineyard area can be set up for flooding (see **Section 3**)
Demand reduction technique	**Works best when:**
In-lieu recharge	Alternative surface water sources are available to replace groundwater for irrigation
Dry farming techniques	Rainfall and water holding capacity of vineyard soil can sustain grape production with little or no supplemental irrigation

*Record your answers on the **Groundwater Recharge Worksheet for Vineyards** (p. 37)!*

5. FINANCIAL ASPECTS OF MAR

The financial resources to conduct MAR can be highly variable depending on the availability of **necessary conveyance and diversion infrastructure, the local costs of water for MAR, and labor costs.**

Costs

If a site already has the conveyance and diversion infrastructure needed to conduct Ag-MAR, such as a surface water pipe, lift pumps, and flood irrigation equipment, there will be little to no investment in infrastructure development. However, if a site needs conveyance infrastructure or does not have a functional flood irrigation system, it could be costly to develop MAR on-site.

Water costs for MAR vary depending on the source of water. Water from flood emergency diversions is free, but water releases from a water district typically are priced per acre-foot diverted.

Finally, labor costs will add up for the time required to start and stop diversions, troubleshoot any field issues, and monitor and report any required field and MAR data. A site may require the construction of berms to contain applied water or other field preparations.

Table 2 shows costs expected for conducting MAR according to a 2016 study. Note that this is for a 160-acre field and excludes the cost of water, since the cost of water can be quite variable. Excluding the cost of water, the annualized costs range from $34 per acre-foot in a single flood year to $89 per acre-foot, accounting for flood flow frequency. These costs are consistent with the costs incurred by case study participants documented in the Recharge Methods Manual.

Table 2. Typical Costs Associated with On-Farm Recharge on a 160-Acre Field. Source: Analyzing Cost Effectiveness for Kings Basin Flood Flow Recovery (M. Cubed, March 2016)

Description	Cost Estimate
Infrastructure	
Surface pipe	$35,000
Lift pumps (4 total, 1 per 40 acres)	$24,000
Fuel for four pumps	$32,500
Labor	
Temporary berm construction	$2,400
Annual ripping or gypsum application	$12,800 ($80/acre)
Irrigation labor	$7,200 ($15/hour)
Annualized costs over 20 years, excluding water costs	
Cost in a single flood year ($/AF)	$34/AF
Cost adjusted for flood frequency of 38% ($/AF)	$89/AF

While the costs of conducting MAR may add up, it is inexpensive compared with other projects and management actions aimed at achieving groundwater sustainability. For example, the rates for recycled water are typically higher. In Napa, the rates for recycled water are approximately $640-$800 per acre. The development of new surface water supplies with new reservoirs or the expansion of existing reservoirs is also quite high. While these types of projects are typically developed by water districts or agencies, the costs are passed down to users of the new water supplies. Finally, demand management, or the reduction of groundwater pumping, represents a real cost to a grower and can be especially high for perennial and high-value crops such as winegrapes, which may experience yield reduction or crop damage for years when irrigation is severely limited, even for a single season. The costs of these alternatives should be considered when evaluating the costs and feasibility of conducting MAR. See **Figure 3** for a comparison of costs for alternative water supply projects. Note that groundwater recharge includes both Ag-MAR, which tends to be on the lower end of the cost spectrum, and dedicated recharge basins, which tend to be on the higher end of the cost spectrum.

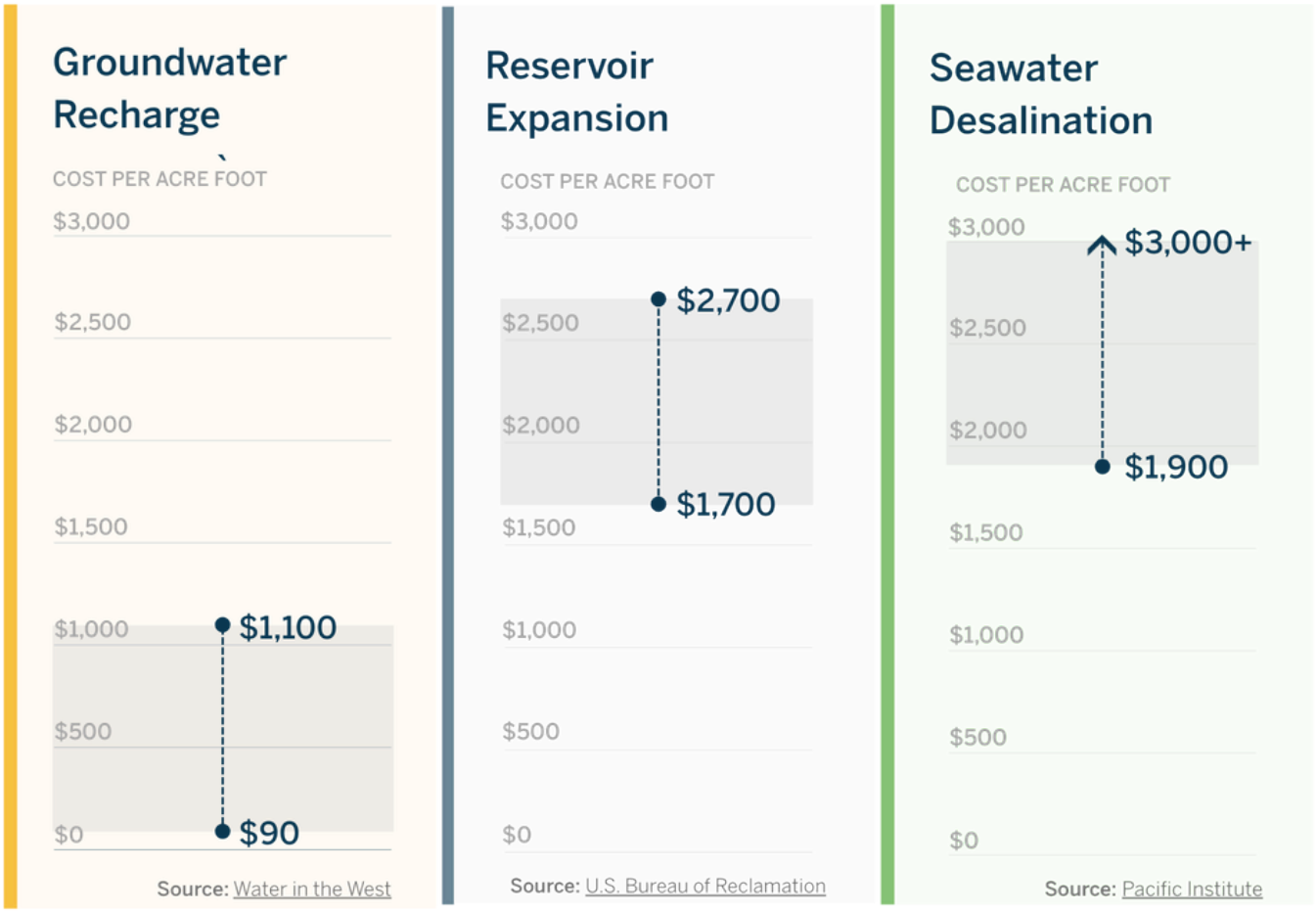


Figure 3. Comparison of costs for alternative water supply projects. Source: Water in the West.

Note that on-farm recharge is typically much more cost-effective than the construction of permanent recharge basins, which require higher construction and maintenance costs and include the opportunity cost of agricultural land being taken out of production.

Decision Support Question:

What additional investments do I need to make to accomplish recharge?

Typical cost categories include infrastructure like pumps, pipelines, or land shaping; labor for set up and management; and purchasing recharge water.

To conduct MAR, I may need to invest in:

- Pump(s)
- Pipeline(s)
- Land shaping
- Labor
- Water purchases
- Other: _____

*Record your answers on the **Groundwater Recharge Worksheet for Vineyards** (p. 37)!*

Incentives

Financial incentives may be available from your water district, GSA, or other organization, which can help partially or fully offset the costs of doing MAR. A range of incentives has been developed by districts and GSAs (see Central Valley Groundwater Recharge Incentives and Strategies report). Examples of MAR incentives include cost-share for capital costs such as water delivery equipment and installation, providing reduced-cost or free surface water deliveries, and even developing groundwater pumping credits. Note that pumping credits can only be generated in those districts or GSAs with pumping restrictions, called allocations, which are not present throughout California. **Consult with your district or GSA to learn about available incentives for conducting MAR.**

Decision Support Question:

Are groundwater recharge incentives available to me? Are they worth it to me to offset costs?

Incentive	Description
Free or reduced-cost water deliveries	Some GSAs or water districts offer free or reduced cost deliveries of district surface water to landowners for recharge purposes.
Pumping credits	Some GSAs or water districts with groundwater allocations offer pumping credits relative to the amount of water a landowner diverts for recharge. For example, a landowner may receive a pumping credit for 50-90% of the volume of water they divert for recharge.
Cost-sharing for equipment and installation	Some GSAs or water districts may offer cost-share assistance for the acquisition and installation of recharge equipment, such as pumps or piping.
Rebates on pumping fees	Some GSAs or water districts that charge groundwater pumping fees offer rebates on such fees for recharge, relative to the amount of water infiltrated.
Multibenefit Land Repurposing Program (MLRP)	Several GSAs have received funding from the California Department of Conservation (DOC) MLRP to support land repurposing projects that protect and restore groundwater, among other benefits.
NRCS Environmental Quality Incentives Program (EQIP)	NRCS EQIP offers financial assistance to growers and landowners interested in implementing resource conservation practices on their land, including surface and groundwater conservation. Financial assistance can include cost-sharing agreements for project implementation as well as advance payment for capital costs in some cases.

Ask your GSA or other groundwater authority about recharge incentives offered in your area, the value of those incentives, and how you might participate.

Record your answers on the ***Groundwater Recharge Worksheet for Vineyards*** *(p. 37)!*

On-Farm Recharge Pilots

Sonoma Wine Country

In Sonoma County, the needs of GSAs to meet the management objectives in their GSP coincide with winegrape producers' needs to secure a reliable water supply. The Santa Rosa Plain GSA, one of three GSAs in Sonoma County, **is piloting on-farm recharge projects using novel water sources to help raise groundwater levels and ensure base flows to the Russian River and Mark West Creek.**

Sonoma County has faced declining groundwater levels for decades, and the first voluntary groundwater management plan for the area pre-dates SGMA by 7 years. That plan was updated to meet the requirements of SGMA in 2022. The plan identified on-farm recharge as a potential way to help the basins retain excess surface water in the aquifer.

Meanwhile, during recent drought years, vineyard operators in the upper and mid-reaches of the Russian River were unable to divert surface water from the rivers for irrigation. They faced millions of dollars of lost production and feared long-term damage to the vines. These growers started looking for ways to fill up their soil profile during winter storms, ensure access to surface water for irrigation, and protect their valuable vineyard assets.

Pilots

Pilot projects in the Alexander Valley and on Mark West Creek are testing the concept of augmenting groundwater levels using existing irrigation systems (both driplines and overhead sprinklers) to spread excess winter water in vineyards. **The studies are measuring soil moisture content and nearby well levels to assess how effective the practice is for improving groundwater conditions, as well as monitoring water quality.**

Growers are watching for effects on their crop and asking these questions: Are vines more vigorous, requiring extra labor for pruning? Have yields improved? What about fruit quality? Is it worth pumping water and maintaining the irrigation system all winter?

Alexander Valley

The first year of the Alexander Valley study started small, with about **50 acre-feet of recharge water applied** to two small vineyard blocks through sprinkler irrigation.

The participating grower reported higher yields in the vineyards that received recharge water. Extra energy costs to pump the water amounted to about $6,000, and other costs included permitting fees and labor for irrigation system maintenance and operation.

Data analysis is still ongoing to assess the value of increased production in contrast to the added costs for recharge operations. The study area will expand to more vineyards in later years of the project.

What's Next?

As the Mark West Creek project gets started and the Alexander Valley pilot expands, more data will clarify the costs and benefits of recharge and its compatibility with vineyard operations. The Santa Rosa GSA hopes to find effective

groundwater replenishment methods in partnership with growers of Sonoma County to improve groundwater conditions in the region.

When asked what they hoped to gain from the study, a participating grower said, "I hope the data speaks for itself- that it helps answer questions growers have about recharge and helps us find some security in our water supply for a reasonable cost."

Acknowledgements

Suzanne Zechiel of Jackson Family Wines and Marcus Trotta of Sonoma County Water Agency were interviewed for this case study.

Partners in the pilot projects include:

Mark West Creek:

- Santa Rosa Plain GSA
- Bachand & Associates
- Sonoma Resource Conservation District

Alexander Valley:

- Dry Creek Rancheria
- Bachand and Associates
- Sonoma Resource Conservation District
- Tom Hammond of Abundance Ag Engineering

Pilot projects are funded by grants from the California Department of Water Resources and the California Department of Conservation.

Insights from Growers

Routine Recharge with Al Costa

Lodi, CA

GSA
San Joaquin County Delta Water Quality Coalition (SJCDWQC)-GSA

Crop
Zinfandel vines (25 acres)

Average annual recharge (2017 – 2025)
~12 ac-ft/acre

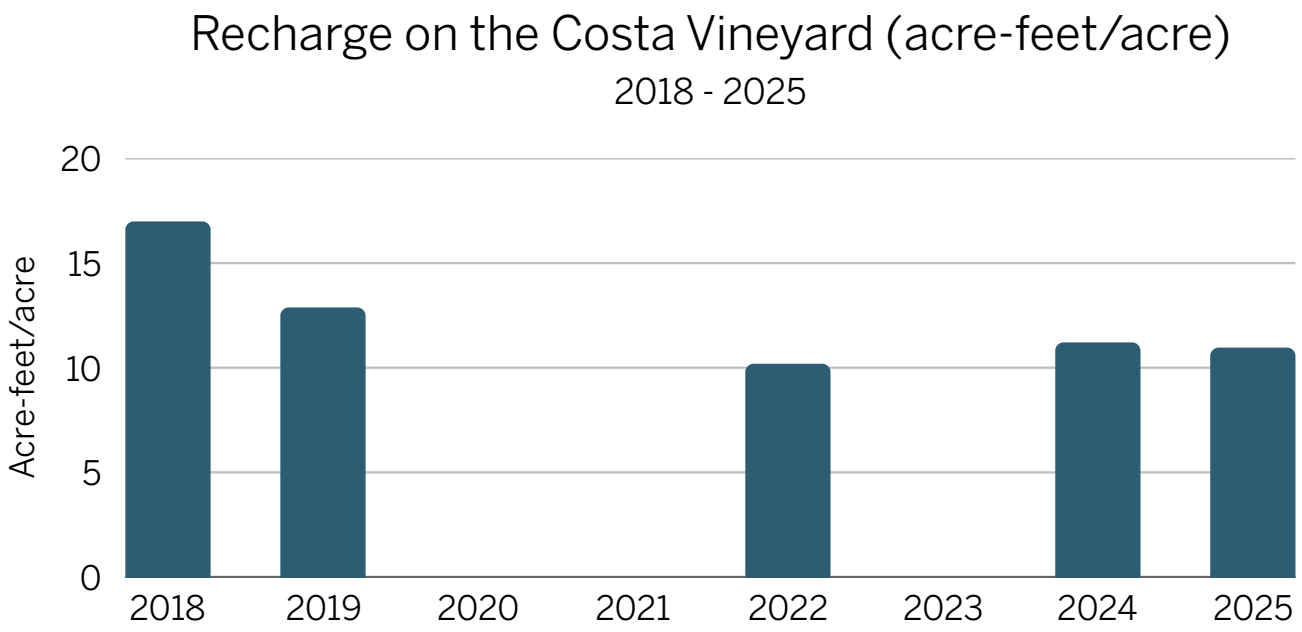
Al Costa during a harvest in the 1970s

Al Costa was an early adopter of on-farm recharge when few farmers participated in the groundwater sustainability practice. Al first tried recharge on 13 of his 25 acres of Zinfandel vines in 2017, leaving the rest as a control field. His sandy soils allowed for aggressive application of recharge water – almost 10 inches in 24 hours on some days – during the very wet winter of 2017-2018, helping him achieve a net recharge of almost 17 acre-feet per acre in his first season!

The effort was not without challenges. First, Al needed a pipeline to bring flood water from the canal to his site, along with a temporary pipe to apply that water to his drip-irrigated orchard. He built low berms around the field's edges to contain the recharge water. He adjusted fertilizer and pesticide treatment schedules prior to recharge to prevent nitrate or crop protection materials from leaching to groundwater during recharge. He and his field crew had to learn to manage irrigation events during the winter while monitoring crop health and doing winter vineyard maintenance. Additional challenges have included broken pipelines, blown electrical panels, drought, flooding, and neighbors' concerns about increases in disease due to excess standing water. Al persisted in on-farm recharge because of the benefits he saw and soon began to recharge on the entire vineyard. Initially motivated by groundwater sustainability for future farm generations, Al quickly recognized more tangible benefits, including reduced salinity in his vineyard's soils. Later during the growing season, he kept a close eye on the vines for any sign of increased powdery mildew or bunch rot, but the recharge field needed the same level of treatment as the control field. While yields weren't greater in the recharge field, they weren't lower either. Al's vineyard served as a demonstration site, and groundwater well monitoring surrounding the farm showed benefit to the groundwater levels.

Over subsequent years, Al has learned how on-farm recharge works for his vineyard, and the practice has become routine for him. His district, the North San Joaquin

Water Conservation District, initially helped with the cost of the conveyance pipeline, subsidized the pumping costs for recharge, and offered the recharge water for free. Al contributed his labor and equipment to set up and manage the field and the recharge events. The incentives from the District still matter to Al, especially the pumping cost reimbursement. As long as his District can help offset those costs, Al expects to be doing on-farm recharge just as routinely as winter pruning.



GROUNDWATER RECHARGE WORKSHEET FOR VINEYARDS

You have completed the Should I do MAR decision tree and are ready to explore MAR options for your property. As you read through the Guide, record your answers to the Decision Support Questions in each section on this worksheet. This worksheet will form an outline to help you develop a customized MAR plan with a Technical Assistance Provider, Groundwater Sustainability Agency, or Irrigation District.

1. **Your objective: Why MAR?** (p. 6)

Check all that apply:

- ☐ Improve long-term groundwater sustainability (SGMA compliance)
- ☐ Reduce risk of dry domestic wells nearby
- ☐ Support streams, wetlands, or other groundwater-dependent habitats (baseflow)
- ☐ Reduce local and downstream flood risk
- ☐ Other: _____

2. **Groundwater Rights** (p. 8)

Find out if you are in a GSA or adjudicated basin here:
https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#boundaries

I am in a:

- ☐ Groundwater Sustainability Agency (GSA)
- ☐ Adjudicated basin
- ☐ Neither

Name of GSA or groundwater authority (if applicable): _____

3. **Water Source** (p. 10)

Do you have any of the following available? (Check all that apply):

- ☐ Winter recharge water delivered by water or irrigation district
- ☐ Water diversions from rivers, streams, or canals during flooding events
- ☐ Surface water sources (overland runoff, winery process water, recycled water) for recharge or to replace groundwater with surface water irrigation
- ☐ Other: _____

Name of Irrigation or Water District: _____

☐ 4. **Water Delivery** (p. 12)

Do you have any of the following available? (Check all that apply):

☐ Farm parcel turnout connected to an irrigation district canal system

☐ Diesel pump to divert excess floodwater

☐ Other: _____

What is the capacity of your turnout or pump? _____ CFS/GPM

Additional infrastructure needed to deliver water:

☐ Pumps ☐ Pipelines ☐ Other: _____

☐ 5. **Recharge Suitability** (p. 13)

Vineyard area (acres): _____

Slope: ☐ Flat ☐ Gently sloped ☐ Steep

Dormant season access to water (Nov–Mar): ☐ Yes ☐ No

For Central Valley growers:

What is the **Recharge Suitability Index (RSI)** rating for the vineyard?

Check here on the GRAT Viewer website: https://gratviewer.earthgenome.org/.
Enter your address and turn on the **Land IQ Groundwater Recharge Suitability layer**.

RSI rating: _____

Outside the Central Valley:

What is the **Soil Agricultural Groundwater Banking Index (SAGBI) rating for the vineyard?**

To view your vineyard's SAGBI rating, enter your address here:
https://casoilresource.lawr.ucdavis.edu/sagbi/

SAGBI rating: _____

Other soil properties from Web Soil Survey (Appendix C), if not covered by RSI or SAGBI: _____

6. **Water Quality Risk** (p. 15)

- ☐ High nitrate leaching risk
- ☐ Recent use (last 6 months) of pesticides on No-Recharge List (refer to Appendix D)
- ☐ Compost, manure, biosolids, or recycled water use
- ☐ Other risk factor: _____
- ☐ Best Management Practices for water quality are of interest to me
  (Contact a Technical Service Provider for advice, see Appendix A)

7. **MAR in the Vineyard**

a. **Vineyard Health & Timing (p. 20)**

Known root or trunk disease present? ☐ Yes ☐ No

Rootstock tolerant of short-term flooding? ☐ Yes ☐ No ☐ Unsure

Planned MAR timing: ☐ Dormant only ☐ Late winter ☐ Other _____

(From the Recharge Timing for Winegrapes, Table 1, Page 22)

Maximum flooding duration per MAR event: _____days

Rate of water application: _____acre-inches per acre per day

Expected dry-down period between MAR events: _____days

Additional days needed for field operations: _____ days

b. **Field Setup**

Maximum allowable depth of water in the vineyard (inches):

_____

I will measure applied water using: ☐ Flow meter ☐ Other method _____

To conduct MAR, my field may need (p. 23):

- ☐ A measuring device, flow meter or other type: _____
- ☐ Berms around the edges of the field ☐ Berms across the middles
- ☐ Berms to contain water to a certain area of the field ☐ Alternate-row flooding
- ☐ No new infrastructure needed ☐ Other: _____

8. Alternative MAR Methods (p. 26)

Ag-MAR or flooding my vineyard won't work well for me. Instead, I'd like to try:

- ☐ Groundwater recharge basin
- ☐ Upslope swale and berm
- ☐ Vineyard swale
- ☐ Flow-through basin
- ☐ Fallow field recharge
- ☐ In-lieu recharge
- ☐ Dry farming

9. Costs, Capacity, & Incentives

Additional infrastructure needed (p. 20):

☐ Pumps ☐ Pipelines ☐ Berms ☐ Leveling

Potential costs for recharge:

☐ Labor ☐ Water purchases ☐ Other

Potential incentives (p. 31):

☐ Free/reduced-cost water ☐ Pumping credits ☐ Cost-share ☐ Unknown

☐ Pumping fee rebates ☐ MLRP ☐ NRCS EQIP

10. Who to Contact Next

Primary contact:

- ☐ Irrigation District
- ☐ Groundwater Sustainability Agency (GSA)
- ☐ Resource Conservation District (RCD)
- ☐ Technical Service Provider (TSP)
- ☐ Natural Resources Conservation Service (NRCS)
- ☐ California Sustainable Winegrowing Alliance (CSWA)
- ☐ Other: _____

Name / Organization: _____

See Appendix A

TABLE OF RESOURCES

Data Resources

Section	Description	Resource URL
Section 1: Why do we need MAR?	Groundwater levels: See the groundwater depths in your region for each year and season.	https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels
	Dry Domestic Well Susceptibility: Determine if you are in or near any dry domestic well susceptible areas.	https://www.arcgis.com/apps/dashboards/f876cfa53ce3466c8b3778e7f4adb50e
	Natural Communities Commonly Associated with Groundwater (NCCAG): A starting point for locating groundwater dependent ecosystems (GDEs), both vegetation and wetland, in your area.	https://usc-word-edit.officeapps.live.com/we/Natural Communities Commonly Associated with Groundwater
	FEMA Effective 100 Year Floodplains: See areas downstream or near you that face flood risk within FEMA's effective 100-year floodplain.	https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#boundaries
Section 2: Preparing for MAR - Legal and regulatory framework	SGMA Data Viewer: Local groundwater governance boundaries: Determine if you are in a GSA, adjudicated basin, or non-basin area.	https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#boundaries
	Sustainable Groundwater Management Act 2019 Basin Prioritization Process and Results, CA Department of Water Resources	https://data.cnra.ca.gov/dataset/13ebd2d3-4e62-4fee-9342-d7c3ef3e0079/resource/ffafd27b-5e7e-4db3-b846-e7b3cb5c614c/download/sgma_bp_process_document.pdf
Section 2: Preparing for MAR – Water sources	Flood Diversions (Water Code 1242.1) information site- State Water Board	https://www.waterboards.ca.gov/waterrights/water_issues/programs/groundwater-recharge/recharge-diversions.html
	Recharge permits information site- State Water Board	https://www.waterboards.ca.gov/waterrights/water_issues/programs/applications/groundwater_recharge/
Section 2: Site Considerations – Soils and Geologic Layers	Soil Agricultural Groundwater Banking Index (SAGBI) A Soil Resources Lab tool to estimate your site's suitability for recharge based on the top 5 feet of soil	https://casoilresource.lawr.ucdavis.edu/sagbi/

	Recharge Suitability Index: A Land IQ tool to estimate your site's suitability for recharge based on surface and subsurface hydrogeology. *Only available for the Central Valley*.	https://gratviewer.earthgenome.org/
	NRCS Web Soil Survey: If your vineyard is not covered by SAGBI or the Land IQ Recharge Suitability Index, Web Soil Survey provides information on your soil that can help you assess your field's recharge suitability. See Appendix C for help using Web Soil Survey.	https://websoilsurvey.nrcs.usda.gov/app/HomePage.htm
Section 2: Site Considerations - Water Quality	Nitrate Leaching Hazard Index, a Soil Resources Lab tool based on soil interpretation, crop, and irrigation. Look up your farm's risk of nitrate leaching into the groundwater.	https://soilmap4-1.lawr.ucdavis.edu/nitrogen-hazard-index/
	Natural Resources Conservation Service Field Office Technical Guide- a catalog of conservation practice standards. Use the "search" function to find information on Avoid, Control, and Trap conservation practices	https://efotg.sc.egov.usda.gov/#/state/CA/documents
	State Water Board Winery Order Permit conditions for discharging winery waste water to land for reuse or disposal	https://www.waterboards.ca.gov/water_issues/programs/waste_discharge_requirements/winery_order.html
	Map and links to Regional Water Quality Control Boards	https://www.waterboards.ca.gov/waterboards_map.html
Section 3: MAR in Vineyards – Vineyard health and MAR	Rootstock Selection Chart based on CDFA Certified Rootstock- Disease Resistance	https://lodigrowers.com/selecting-a-rootstock-for-a-winegrape-vineyard/
	Rootstock Selection Chart including flood tolerance	https://studylib.net/doc/26107857/rootstock-selection-uc-davis
Section 3 – MAR in Vineyards – Preparing vineyards for recharge	Project Apis m. **Seeds for Bees program** (Cover crops that support pollinators)	https://www.projectapism.org/sfb-home
	Cover Cropping in Vineyards: A Grower's Handbook. Available for purchase ($35) from UC Agriculture	https://anrcatalog.ucanr.edu/Details.aspx?itemNo=3338

	and Natural Resources. Publication 3338. (1998).	
	Collection of **California-specific cover crop information**. Includes resources, tools, and links covering species selection and cover crop management.	https://ucanr.edu/site/california-cover-crops-resources
	Expert Grower Database: Cover Cropping Practices in Orchards and Vineyards Access case studies of vineyards using cover crops.	https://sarep.ucdavis.edu/covercropsdb
	North Coast Soil Hub Resource Library Includes locally- tested recommendations for cover crops in vineyards	https://soilhub.org/resource/?_media_copy_copy=cover-crops
	Western Cover Crops Council Cover crop information for the Pacific Northwest and California	https://westerncovercrops.org/2024/06/24/perennial-cropping-systems/
Section 4 – Alternative MAR and groundwater reduction methods	NRCS Conservation Practice Standard "Groundwater Recharge Basin or Trench"	https://efotg.sc.egov.usda.gov/api/CPSFile/30312/___
	NRCS Conservation Practice Standard "On-Farm Recharge"	https://efotg.sc.egov.usda.gov/api/CPSFile/30313/___
	NRCS Conservation Practice Standard "Terrace"	https://efotg.sc.egov.usda.gov/api/CPSFile/48684/600_CA_CPS_Terrace_2024_pdf
	"Building multi-benefit recharge basins" design guide	https://www.edf.org/sites/default/files/documents/Groundwater%20recharge%20guidelines%20checklist_web_0.pdf
	"Dry Farming in California Vineyards: A Guide for Winegrape Growers" CSWA resource hub	https://sustainablewinegrowing.org/projects/
	Dry Farming Wine Grapes: A Best Management Practice Guide for California Growers (2015) by CAFF and CSWA	https://caff.org/wp-content/uploads/2011/08/CAFF-Dry-Farming-BMP-Guide_web.pdf
Section 5 – Financial Aspects of MAR	**Central Valley Groundwater Recharge Incentives and Strategies**	https://suscon.org/wp-content/uploads/2023/08/Central-Valley-Groundwater-Recharge-Incentives-and-Strategies_final.pdf

	"On-Farm Recharge Methods Manual" by Sustainable Conservation	https://suscon.org/wp-content/uploads/2023/08/Recharge-Methods-Manual_Case-Studies_2023.pdf
	"Analyzing Cost Effectiveness For Kings Basin Flood Flow Recovery" by M. Cubed for Sustainable Conservation (2016)	https://suscon.org/wp-content/uploads/2018/02/M3-Recharge-Model-Report_040616.pdf

GLOSSARY OF TERMS AND ACRONYMS

Ac-ft	Acre-foot. Also abbreviated AF. Volumetric measure of water equal to one acre in area and one foot deep. Equals 43,560 cubic feet or 325,851 US gallons.
AF	Acre-foot. See "Ac-ft", above.
Ag-MAR	Agricultural Managed Aquifer Recharge. The act of intentionally flooding fallow, dormant, or active cropland when excess surface water is available. See On-farm Recharge, OFR.
Baseflow	Sustained streamflow which is primarily fed by groundwater discharge, not directly from precipitation. This is also referred to as groundwater flow, or dry-weather flow.
Berm	A low ridge constructed of compacted soil that intercepts, directs or contains shallow overland flows of water.
CFS	Cubic Feet per Second. A volumetric flow rate for water. A flow rate of 1 CFS for 24 hours would deliver approximately 2 AF.
Diversion	The California State Water Board defines diversion as "taking water by gravity or pumping from a surface stream or subterranean stream flowing through a known and definite channel, or other body of surface water, into a canal, pipeline, or other conduit, and includes impoundment of water in a reservoir".
Diverter	A person or entity (such as a water district) making a diversion, as defined above.
Flood-MAR	Flood-Managed Aquifer Recharge. A water management strategy using high flows for managed aquifer recharge of agricultural lands, working landscapes, and natural managed lands.
FTB	Flow-Through Basin
GPM	Gallons per Minute. A volumetric flow rate for water. A flow rate of 100 GPM for 1 day would deliver approximately 0.44 AF.
GRAT	Groundwater Recharge Assessment Tool
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
ILR	In-lieu Recharge
Leaching	The process by which soluble materials are dissolved from their solid form into liquid and then moved by the liquid. For example, nitrate or salts in solid form in soils dissolve into soil water and then can percolate toward the water table by gravity.
MAR	Managed Aquifer Recharge. The purposeful recharge of water to aquifers for subsequent recovery or for environmental benefit.
MLRP	Multi-benefit Land Re-Purposing
Nitrate	A compound of nitrogen and oxygen with the chemical formula NO^-_3. This negatively charged ion is very soluble in water and does not adsorb to soil particles. Salts containing this ion are called nitrates, and are common components of fertilizers.
NRCS	Natural Resources Conservation Service, an agency of the United States Department of Agriculture (USDA) https://www.nrcs.usda.gov/
OFR	On-Farm Recharge. See Ag-MAR. The act of intentionally flooding fallow, dormant, or active cropland when excess surface water is available.
PFAS	Per- and Polyfluoroalkyl Substances
RCD	Resource Conservation District, a special district of the State of California that operates under the direction of a local board of landowners. https://carcd.org/
RSI	Recharge Suitability Index
SAGBI	The Soil Agricultural Groundwater Banking Index
SGMA	Sustainable Groundwater Management Act
Swale	A shallow landscape depression between ridges, characterized by gentle side-slopes, which tends to hold or convey water.
TSP	Technical Service Provider
Water Code 1242.1	A provision of the California Water Code which allows parties to divert flood water for groundwater recharge without a water right, if in compliance with certain requirements. See the Information Resources table for a link to the State Water Board website for more information.

APPENDIX A: TECHNICAL ASSISTANCE PROVIDER LIST

Technical Assistance Resource	Description	How to find them
Local Irrigation District	Districts manage surface water and conveyance structures	There is no central directory; search for your local District online
Local Groundwater Sustainability Agency (GSA)	Local GSA and local county recharge incentives for recharge.	GSA Map Viewer
County Farm Bureau	Grower advocacy group with local chapters which may be involved in water issues	https://www.cfbf.com/about-the-farm-bureau/counties
Resource Conservation Districts (RCDs)	Special districts of the State of California with their own local boards of directors made up of landowners in the District.	https://carcd.org/page/regions
County UCCE Farm advisors	Specialized advisors for water resources and irrigation	https://ucanr.edu/counties
USDA Natural Resources Conservation Service (NRCS) Field offices	On farm recharge incentive pilot program through Environmental Quality Incentives Program (EQIP) Available only in select areas of San Joaquin Valley as of 2026.	https://offices.sc.egov.usda.gov/locator/app
SELF HELP Enterprises	Community based organization in the Central Valley that provides access to various financial resources, engages local concerned community members who want to ensure sustainability and healthy soils. Language access services available.	https://www.selfhelpenterprises.org/
California Sustainable Winegrowing Alliance (CSWA)	CSWA is a nonprofit organization that encourages adoption of sustainable winegrowing practices through education, outreach, certification and partnerships.	https://sustainablewinegrowing.org/
Sustainable Conservation: Water for the Future program	Sustainable Conservation advances the collaborative stewardship of California's land, air, and water for the benefit of nature and people. Our Water for the Future team works to ensure clean, reliable water for everyone by implementing on-farm recharge and building watershed recharge modeling.	https://suscon.org/project/water-for-the-future/

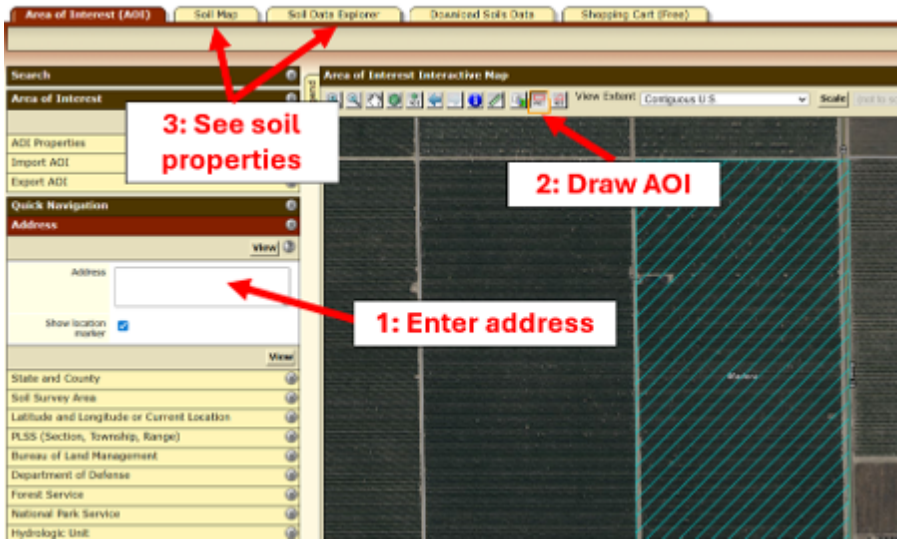
APPENDIX B: RECHARGE DATA SHEET

On Farm Recharge - field sheet										Additional information in this column (examples of additonal data to be collected)
Grower name:										What application method was used? (e.g. alternate rows, berms/no berms, etc) How deep did the water get? How long did water stand on the field? Any rainfall during recharge? Was there any seepage in adjacent fields or ditches? Was there any sedimentation? Did you see any crop health issues? Any other challenges during recharge? Did you see any wildlife using the water on the field? (EXTRA notes on back of sheet)
Field ID:										
Address:										
Crop/Total field Acreage:										
Actual acreage recharged										
Pump ID/Turnout ID	Date	Start Time		**Flow Meter at Start time**		Stop Time		Flow Meter at Stop time		
Event #	(Fecha)	(Hora de Empezar)		(el medidor de flujo a hora de empazar)		(Hora de Finalizacion)		(el medidor de flujo a hora de finalizacion)		
1			am / pm		ac-ft or gpm		am / pm		ac-ft or gpm	
2			am / pm		ac-ft or gpm		am / pm		ac-ft or gpm	
3			am / pm		ac-ft or gpm		am / pm		ac-ft or gpm	
4			am / pm		ac-ft or gpm		am / pm		ac-ft or gpm	
5			am / pm		ac-ft or gpm		am / pm		ac-ft or gpm	
6			am / pm		ac-ft or gpm		am / pm		ac-ft or gpm	
7			am / pm		ac-ft or gpm		am / pm		ac-ft or gpm	
8			am / pm		ac-ft or gpm		am / pm		ac-ft or gpm	
9			am / pm		ac-ft or gpm		am / pm		ac-ft or gpm	
10			am / pm		ac-ft or gpm		am / pm		ac-ft or gpm	

APPENDIX C: USING WEB SOIL SURVEY TO FIND SOIL PROPERTIES RELATED TO RECHARGE

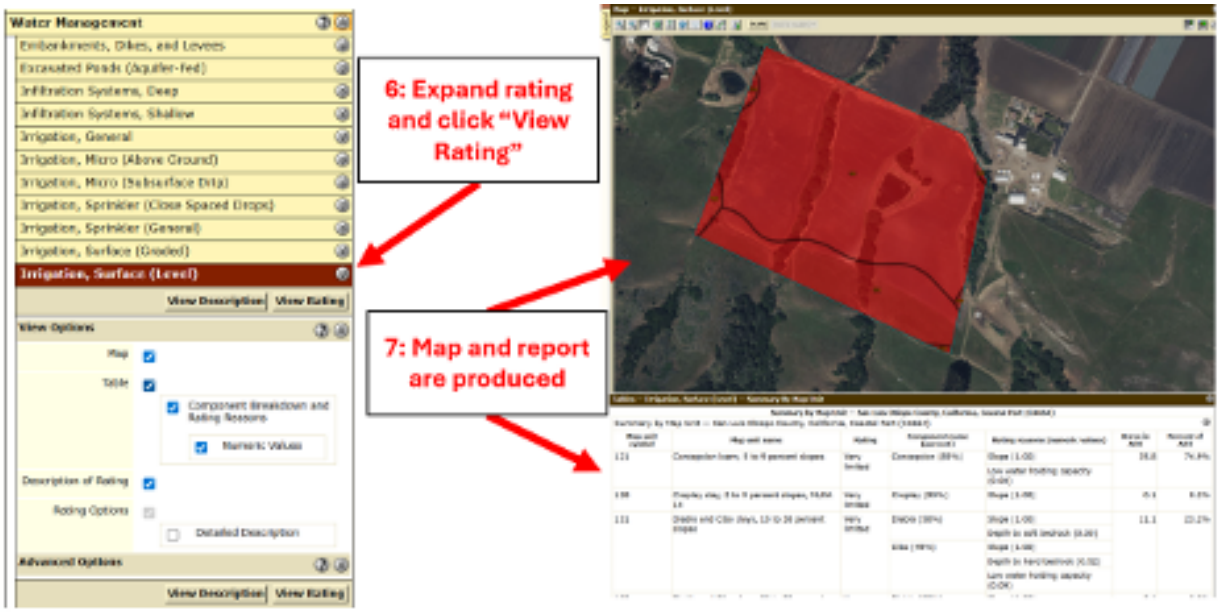
To view your vineyard's soil properties, go to the NRCS Web Soil Survey website and click the big green button.

1. Under ***Quick Navigation*** select ***Address***. Enter your address and select ***View***.
2. Draw an ***Area of Interest (AOI)*** around your field- this can be a rectangle or a polygon.
3. Select ***Soil Map*** tab to view the breakdown of soil types on your field.

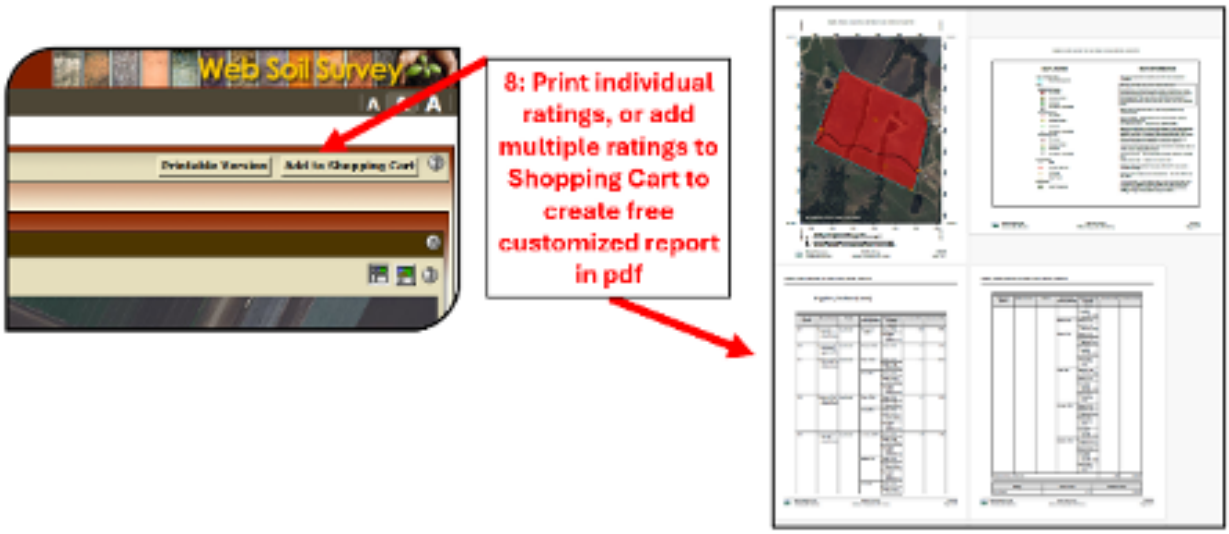


4. Select ***Soil Data Explorer*** tab and a sub-tab (either ***Suitabilities and Limitations for Use*** or ***Soil Properties and Qualities)*** to view your field's ratings based on different suitability factors and limitations.
5. Expand the category to find ratings of interest.

6. Expand the rating of interest and click ***View Rating***.
7. A map and report of the rating's values for soils in your Area of Interest are created!



8. To create a report, you can click ***Printable Version*** for a single rating, or ***Add to Shopping Cart*** to create a report with multiple ratings. The reports are free and are created in PDF suitable for downloading or printing.



SOIL PROPERTIES RELATED TO RECHARGE, AND WHERE TO FIND THEM:

Soil Properties and Qualities tab		
Category	**Rating title**	**Recharge guidance**
Water Features	Depth to Water Table	If the water table is 5 feet (152 centimeters) or less from the ground surface, soil is unsuitable for recharge.
Soil Physical Properties	Surface Texture	Texture classes with more sand and less clay are more suitable for recharge.
Soil Qualities and Features	Depth to Any Soil Restrictive Layer	If a restrictive layer is 5 feet (152 centimeters) or less from the ground surface, soil is unsuitable for recharge.
Soil Qualities and Features	Drainage Class	Well-drained soils are more suitable for recharge.
Suitability and Limitations for Use tab		
Category	**Rating title**	**Recharge guidance**
Water Management	Infiltration Systems, deep	Soils with low or no limitations will be more suitable for recharge basins or swales.
Water Management	Irrigation, Surface (Graded) or (Level)	Soils with low or no limitations will be more suitable for Ag-MAR.
Land Management	Nitrate Leaching Potential, Irrigated	Rates the potential for nitrate to leach below the root zone in categories of Low, Moderate, Moderately High, and High potential for leaching.
Land Management	Pesticide Leaching Potential	Rates the limitations of land use based on potential for pesticide leaching. “Not limited” indicates low potential for pesticide leaching while “Very limited” indicates high potential for leaching.

APPENDIX D: "NO RECHARGE" PESTICIDE LIST

These chemicals are restricted by the California Code of Regulations, Title 3. Food and Agriculture, Division 6. Pesticides and Pest Control Operations: Chapter 4. Environmental Protection, Subchapter 1. Groundwater; Article 1. Pesticide Contamination Prevention. Section 6800(a) Groundwater Protection List.

- Some products are labeled simply by the chemical name.
- This list is not exhaustive.
- **It is the responsibility of the recharger to ensure that products containing these materials are not used within 6 months of a recharge event.**

Chemical name	Common names
Atrazine	AAtrex, Empyros Triad, Helmet Maxx, Stalwart 3W, Visor S-MOC ATZ, Ravine, Impact Z, Vilify, ATRA-V 4L, Volley ATZ NXT
Simazine	Simazat 90DF, Simazat 4L, Sim-Trol 4L, Princep Caliber 90, Princep 4L, Princep Liquid
Bromacil	DiBro 2+2, DiBro 4+2, Sweep, Weed Blast, BareSpot Ureabor, Hyvar X, Hyvar X-L, Krovar I DF
Diuron (Exception: Products with less than 7% diuron applied to foliage)	Bromacil/Diuron 40/40, Velpar AlfaMax Gold, NovaSource Velpar AlfaMax, Parrot 4L, Parrot DF, Karmex DF, Direx 4L, Cleanshot DF, Sweep, Weed Blast, Nufarm Imazuron Herbicide, BareSpot Weed & Grass, Mojave 70 EG, Krovar I DF, DiBro 2+2, DiBro 4+2, Sahara DG
Prometon	Pramitol 5PS, Pramitol 25E (Labeled for use on non-crop areas)
Bentazon	BashAzon, Varisto, Broadloom, Basagran 5L, Basagran T & O, Storm, Rezult B
Norflurazon	Solicam DF, Evital 5G

Regulation appears in California Code of Regulations, Title 3. Food and Agriculture, Division 6. Pesticides and Pest Control Operations: Chapter 2. Pesticides, Subchapter 4. Restricted Materials, Article 5. Use Requirements, Section 6487.1 Artificial Recharge Basins.

And in Chapter 2. Pesticides, Subchapter 4. Restricted Materials, Article 5. Use Requirements, Section 6487.5 Leaching Groundwater Protection Areas.