SUSTAINABLE GROUNDWATER MANAGEMENT (SGM) GRANT PROGRAM

*The following is an excerpt from the Flood-MAR Monitoring Method [MM-03]*

## SGM Grant Program Requirements for Post-Performance Monitoring and Reporting

# Flood-MAR Monitoring Method

| | |
|---|---|
| **Project / Action Type** | Flood-MAR uses unallocated surface water flood flows as a water source for managed aquifer recharge (MAR). |
| **Similar / Related Project Types** | Flood-MAR is generally used to describe groundwater recharge on agricultural lands and working landscapes. It is commonly referred to as “on-farm recharge” or “ag-MAR”. A related project type is floodplain restoration that in addition to other benefits, allows for greater groundwater recharge from streams. |
| **Primary Metric** | Groundwater levels.<br>Groundwater storage.<br>Applicable water quality constituents<br>Change in ground levels (situationally).<br>Surface water flow rates (situationally).<br>Surface water stage (situationally).<br>Groundwater dependent ecosystems (situationally). |
| **Measurement Unit** | Groundwater levels measured in feet in a consistent vertical datum.<br>Recharge/demand volumes in acre-feet.<br>Concentration or measurement of applicable groundwater quality constituents (typically mg/L), including nitrate, salinity, arsenic, selenium, boron, or other applicable water quality constituents of concern. |
| **Beneficial User** | Municipal and domestic water supply (MUN)<br>Agricultural water supply (AGR)<br>Groundwater recharge (GWR)<br>Freshwater replenishment to surface waters (FRSH) (situationally) |

## Approach to Implementing Flood-MAR Monitoring

Flood-MAR is a relatively new approach being used to increase groundwater recharge and promote multi-benefit use of available flood waters. Water sources for Flood-MAR projects are flood flows in streams or reservoir releases timed to discharge water in advance of forecasted rain events (see Figure 1 for example).

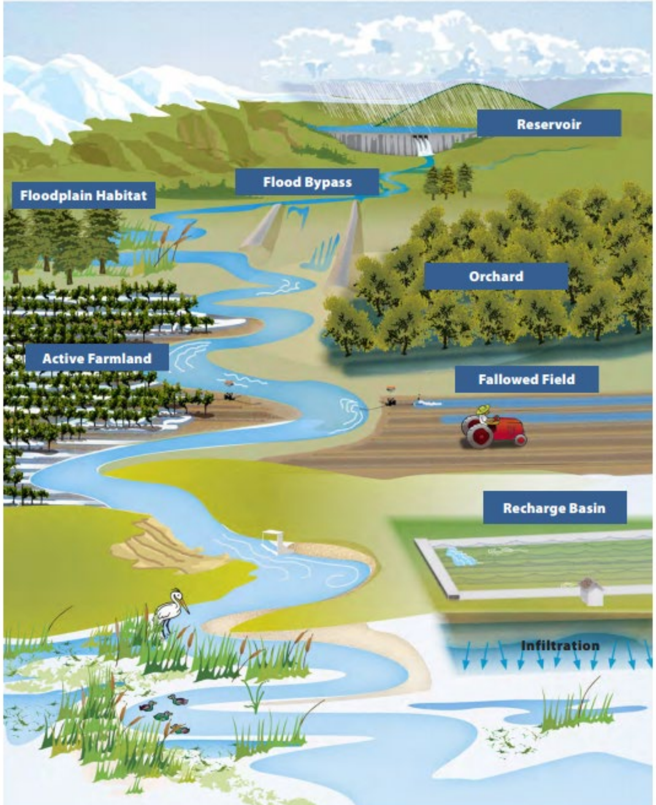


**Figure 1. General elements of a Flood-MAR project from DWR 2018.**

The recharge mechanism is not specific to Flood-MAR, though many proposed or planned Flood-MAR projects intend to utilize an on-farm recharge approach (also known as Ag-MAR). On-farm recharge or flooding suitable dormant crops and fallowed land during the irrigation off-season, generally consists of spreading flood water over a large area at a relatively shallow ponding depth (generally 1- to 2-feet). Maintaining a shallow ponding depth provides recharge to shallow groundwater and limits potential risks associated with the approach, including soil erosion or damage to irrigation infrastructure. Identifying areas with more permeable soils and fewer low permeability perching layers can increase the rate of recharge while maintaining a shallow ponding depth (see Figure 2 for an example Flood-MAR facility).

The primary concern about Flood-MAR projects is the potential to degrade groundwater quality with nitrate, salts, arsenic, and/or other constituents present in the soil matrix of the vadose zone. Surface water used for recharge almost always contains less nitrate, salts, and other applicable constituents than agricultural soils. Monitoring for these constituents of concern is important in assessing the effects of Flood-MAR recharge projects.

A secondary concern about Flood-MAR projects is slow percolation or ponding of water caused by low-permeability soils or soils with restrictive perching layers in the shallow subsurface. High water tables can cause waterlogging of roots, which promotes anaerobic conditions that might affect plant health due to the lack of oxygen. Slow percolation can increase mobilization of applied nitrate, chemicals, and salts from the unsaturated vadose zone to groundwater.

## Justification

Flood-MAR monitoring methods are dependent on the goals of the project and should therefore be designed to assess specific project benefits and unintended consequences. The description below is divided into primary monitoring, that should be conducted to assess whether the project is functioning, secondary monitoring, which would be beneficial to track the overall project benefits for grant purposes, and additional useful monitoring, which could help track overall project performance and help establish useful metrics for future project implementation.

### Primary monitoring

Groundwater levels and groundwater quality monitoring should be conducted for most Flood-MAR projects. Monitoring groundwater levels and groundwater quality allows the project proponent to measure project benefits and assess potential impacts to groundwater quality that might affect beneficial use. While Flood-MAR projects should generally benefit groundwater quality, there may be short-term impacts to groundwater quality from flushing constituents present in the soil matrix.

Groundwater level monitoring should include monitoring wells or piezometers installed in the shallow aquifer. Groundwater monitoring in deeper aquifers or permeable layers of the aquifer should be conducted to a depth where the project benefit or impact is negligible. Multiple layers of groundwater level monitoring in and around the recharge area can help assess increases in groundwater levels and groundwater storage due to recharge, relative to dynamic background conditions. Groundwater level monitoring upgradient and downgradient for a Flood-MAR project site can also help identify changes to groundwater flow or gradient induced by large volumes of groundwater recharge. In areas prone to perched groundwater, vadose zone piezometers may be installed to the tops of potential impeding layers to monitor development of perched groundwater conditions and lateral flow.

Groundwater quality should be assessed in the shallowest aquifers that could receive recharge water and subsequently deeper aquifer zones to assess the potential effect of flushing constituents of concern. Furthermore, groundwater quality monitoring should be conducted between the recharge site and beneficial users such as domestic or public supply well owners to identify potential risks to groundwater quality degradation in drinking water supply wells before they occur. If there are no drinking water supply wells near project sites, then groundwater quality monitoring is less critical as there are fewer receptors for degraded groundwater.

In areas where initial groundwater is far below ground surface and not affected by surface recharge, the project proponent may be able to demonstrate that groundwater monitoring is neither feasible nor beneficial. An analysis of groundwater occurrence and use beneath and downgradient of a project site should be conducted to determine whether monitoring is not needed or feasible.

## Secondary monitoring

Monitoring the volume and rate of water applied and recharged is an important consideration to assess project operation. The volume of applied water should be measured at the project diversion point. After the water is diverted, there are system losses that could be accounted for and calculated to estimate the groundwater recharge volume at the project location.

## Additional useful monitoring

A water budget may be useful to assess the project benefits. A calibrated groundwater model can be used to estimate the total volume of groundwater recharged and how much water was lost to evapotranspiration, lateral flow to neighboring areas, discharge to streams, etc. Quantifying the water budget for recharge projects with field monitoring is possible; however, this can be both challenging and costly with the technology that is currently available.

In some cases, other sustainability indicators might benefit from Flood-MAR projects. 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 Apply the Flood-MAR Monitoring Method

Implementation of appropriate and effective monitoring methods for Flood-MAR projects includes the following strategies and steps:

Figure 2. Example of orchard utilized as Flood-MAR facility (DWR, 2018).

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. Flood-MAR projects may require a Safety Plan to address these and other potential safety concerns.
2. **Monitoring network:** Identify and map drinking water supply well locations near the recharge area to design a monitoring network that can assess and track the risk of potential impacts to beneficial users by changes in groundwater levels and groundwater quality degradation. 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).

1. **Install monitoring wells:** Identify and/or install groundwater level and quality monitoring wells in each saturated zone or aquifer beneath the recharge area that may be influenced by groundwater recharge. This may include vadose zone monitoring if perched conditions are expected to develop because of the recharge project. Wells should ideally be placed in and around the recharge area, including upgradient, cross-gradient, and downgradient, to assess the changes to groundwater level, gradients, and quality from natural processes, relative to the Flood-MAR project.
2. **Baseline conditions:** Conduct “baseline monitoring” in the monitoring wells prior to commencement of recharge operations to document groundwater levels and trends, and to characterize ambient groundwater quality and trends. While baseline monitoring for groundwater levels and quality should be conducted at a minimum prior to commencement of recharge operations, collecting baseline monitoring for at least one year before recharge operations during prior seasonal low and seasonal high groundwater level periods would provide a more robust dataset to compare to project implementation data should groundwater level or quality degradation occur.
3. **Event monitoring:** During recharge events measure groundwater levels continuously (at least daily) using groundwater level transducers to estimate changes in groundwater level, groundwater gradients, and potential groundwater and surface water interconnection.
4. **Post-event monitoring:** After initial recharge events, groundwater quality for constituents of concern should be measured monthly. The frequency can be reduced to annually at the conclusion of the recharge event. Monitoring frequency for groundwater levels and/or quality can be reduced in subsequent recharge events if initial findings suggest that less frequent monitoring is necessary.
5. **Event reporting:** Compile estimates of groundwater diverted for Flood-MAR, recharge induced, and benefits and impacts on groundwater levels and groundwater quality annually.
6. **Groundwater modeling for refinement of project:** Use a calibrated groundwater model, as necessary, to refine estimates, or projections, of benefits and impacts related to the project.

## Data and Protocols - Fundamentals

### Information/Data Requirements

Flood-MAR monitoring primarily focuses on the effects that recharge may have on groundwater levels and groundwater quality. Additionally, it can be useful to monitor the volume of water diverted for recharge. The following monitoring tools, at a minimum, should be used to monitor Flood-MAR projects:

- Groundwater level changes should be measured in wells at different depths beneath and around the recharge area. The volume of water that recharges the groundwater aquifers or flows laterally on subsurface aquitards may be estimated using the change in groundwater levels in wells at different depths beneath and around the recharge area. Groundwater levels measured during baseline monitoring and after recharge events can be evaluated to assess changes to groundwater gradients related to project implementation.

- The monitoring network may use existing groundwater level monitoring wells if they are available and constructed appropriately. New shallow monitoring wells in an unconfined aquifer should be constructed in the upper part of the pre-recharge saturated zone with the screened interval extending above the water table to accommodate water level rise from recharge operations. The length of screen below and above the pre-recharge water table depend on the range of seasonal fluctuation of background water levels and the anticipated amount of water level rise from recharge. Vadose zone piezometers should be installed to the tops of potential impeding layers that may cause development of perched groundwater conditions and lateral flow. Since groundwater elevations are dynamic properties, background groundwater level measurements in upgradient, downgradient, and/or cross-gradient wells are useful to estimate natural changes in groundwater elevation unrelated to the groundwater recharge project.

- Groundwater quality should be assessed during implementation to avoid project impacts to beneficial use of groundwater for drinking water supply. Groundwater quality is best monitored by sampling and analysis at wells. The primary constituents of concern in the agricultural setting where many Flood-MAR projects are planned are nitrates and salts. Other potential constituents of concern in the agricultural setting are naturally occurring within the geologic material or are found in applied chemicals. Often, groundwater quality for beneficial use is assessed relative to the applicable maximum contaminant level for drinking water; however, in some cases can also be related to crop tolerance. Applied chemicals and natural constituents in the agricultural setting that may be useful to periodically monitor include pesticides, herbicides, soil fumigants (for example, 1,2,3-trichloropropane), arsenic, boron, selenium, and potentially other minerals, metals, and geochemical parameters. Other existing sources of groundwater quality data can be used to monitor project impacts if the wells are in the vicinity of the project area. Water quality in public supply wells is monitored and reported for large systems by the State Water Resources Control Board Division of Drinking Water and for small systems by local county Environmental Health Departments. Additionally, shallow domestic well water quality data are available in parts of the state (San Joaquin and Salinas Valleys) from the Regional Water Quality Control Board Irrigated Lands Reporting Program with expansion of the program into the Sacramento Valley planned to start in 2022.

Additional useful monitoring to assess the project effectiveness and performance includes the volume of applied water, fate of applied water, and benefits to other sustainability indicators:

- The volume or rate of surface water used by the project can be measured upstream or at the diversion and downstream of the diversion. Streamflow is typically measured using a discharge curve developed for different stream stages at a stream gage or stilling well. Stream levels or stage are typically measured at least daily with pressure transducers.

- Water flux in the vadose zone can be estimated using tensiometers for measuring soil water tension. Vertical hydraulic conductivity soil and sediment properties in the vadose zone can either be measured or estimated to calculate a recharge volume from tensiometer data.

- The volume of water that returns to streams and benefits interconnected surface water can be estimated using shallow groundwater level measurements in wells or piezometers generally perpendicular to the stream. In some cases, streamflow measurements upgradient and downgradient of the recharge locations are useful for assessing interconnected surface water (see interconnected surface water monitoring section).

- Water lost to evapotranspiration can be measured using a combination of weather data, lysimeters, and soil moisture measurements.

Table 1 provides an example summary table of monitoring metrics that could be used for reporting on the benefits of Flood-MAR projects.

***Table 1.*** **Example Data Monitoring Report (Generally Annually)**

| Monitoring Reporting | |
|---|---|
| Annual Precipitation / % of Avg Precipitation | XXX inches / +/- XXX % |
| Number of Flood-MAR Events | XXX |
| Total Diversion | XXX AF |
| Estimated Total Recharge to Pumping Aquifers | XXX AF |
| Average Groundwater Level Change (Recharge Area / Background) | +/- XXX ft / +/- XXX ft |
| Average Groundwater Quality Constituent Change (list all identified, Recharge Area / Background) | +/- XXX mg/L / +/- XXX mg/L |
| Incurred Costs | $XXX |

## Data Analysis and Reporting

1. **Analyze monitoring data:** Monitoring data should be used to evaluate the effectiveness and performance of Flood-MAR projects. Determine any limiting factors on performance and identify options for improving performance, as needed. As operations continue, this assessment should include evaluating possible areas of increasing concern of unfavorable impacts or risks, such as causing unreasonable harm to nearby land or beneficial water uses. In addition, the evaluation should address if and how operations can be better managed to avoid significant impacts and/or risks.
2. **Prepare reports and manage data:** Reporting 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 should be uploaded to the DWR system annually and progress on project implementation and monitoring should be provided in Annual Reports. If the project is associated with a Groundwater Sustainability Plan, the annual project summary should be provided in Groundwater Sustainability Plan Annual Reports and a full project performance assessment should 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 §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 State Water Resources Control Board.

## Key Protocols

The following protocols should be followed for required monitoring:

- 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).
- Technical and reporting standards included in California Water Code §352 *et seq*.

Additional guidance or references include:

- Surface water discharge measurement protocol, available from the United States Geological Survey (USGS, 2010).