SUSTAINABLE GROUNDWATER MANAGEMENT (SGM) GRANT PROGRAM

The following is an excerpt from the Aquifer Storage and Recovery Monitoring Method [MM-01]

SGM Grant Program Requirements for Post-Performance Monitoring and Reporting

Aquifer Storage and Recovery (ASR) Monitoring Method

Project / Action Type	Aquifer Storage and Recovery (ASR) utilizes different water sources for managed aquifer recharge and recovery benefits within an aquifer. Many ASR projects inject highly treated or recycled water into deep aquifers. This typically occurs in historically over-drafted and high-demand basins to bank or recharge water for subsequent recovery and extraction.
Similar / Related Project Types	ASR directly and actively injects water into groundwater with immediate volumetric results. Other groundwater recharge projects (Recharge Ponds, Flood-MAR, Stormwater Recharge) are directly related and use similar implementation and permitting approaches to ASR. However, these other groundwater recharge methods are slower and more passive in recharging groundwater. ASR can be used to decrease surface water depletion, in interconnected surface waters, reduce seawater intrusion, and reduce subsidence, and are generally secondary benefits of ASR projects in California.
Primary Metrics	Groundwater levels. Groundwater storage. Applicable water quality constituents. Change in ground levels (situationally). Surface water flow rates (situationally). Surface water stage (situationally). Groundwater dependent ecosystems (situationally).
Measurement Units	Groundwater levels measured in feet in a consistent vertical datum. Recharge/demand volumes in acre-feet. Concentration or measurement of applicable groundwater quality constituents (typically mg/L), including disinfection byproducts, microbial communities, emerging contaminants such as Per- and Polyfluoroalkyl Substances (PFAS) or pharmaceuticals, arsenic, iron, manganese, nitrogen, salts, selenium, sulfur, metals, pesticides, or any other applicable constituent of concern.
Beneficial Users	Municipal and domestic water supply (MUN) Industrial service supply (IND) Industrial process supply (PROC) Agricultural water supply (AGR) Groundwater recharge (GWR) Freshwater replenishment to surface waters (FRSH)

Approach to Implementing Aquifer Storage and Recovery Monitoring

The method for selecting appropriate monitoring locations and types for ASR implementation depends on the geological and geochemical makeup of the aquifers; the beneficial use of these aquifers; the recharge water source; the intended use of the water supply, and the anticipated benefits and impacts of the project. Aquifers are naturally dynamic, often changing over time with water quality concentrations both vertically and horizontally. ASR operations monitoring wells are recommended for measuring groundwater levels and water quality over time (i.e., disinfection byproducts, arsenic, total dissolved solids, etc.). In addition, ASR projects have both injection and recovery cycles, so monitoring should be designed to assess the benefits and impacts associated with both cycles.

Justification

ASR projects can potentially provide benefits for each of the six SGMA sustainability indicators; therefore, monitoring methods are dependent upon the goals of the project. The groundwater monitoring networks should be designed to assess project benefits and unintended consequences. At a minimum, the monitoring methods for ASR projects should measure the quality of the water injected, the effect of groundwater level change in the aquifer, and groundwater quality in the aquifer. The volume and rate of water injection and extraction to and from the target aquifers is valuable information for project operation and has water quality implications.

Primary Monitoring

Groundwater level monitoring is critical to assess the benefit and impacts of ASR projects. In general, the monitoring should include wells installed in the target aquifers and should consider and monitor impacts on the overlying shallower aquifers, if applicable. Groundwater level monitoring in and around the ASR area helps assess the increase in groundwater levels and associated groundwater storage, relative to dynamic background conditions. Groundwater level monitoring also can help identify changes to groundwater flow or gradient induced by increased volumes of groundwater in storage.

Groundwater quality monitoring should be implemented for ASR projects, as there are potential impacts to water quality. However, most ASR projects should provide clean water for injection in accordance with the SWRCB Title 22 water quality standards (SWRCB, 2018). Groundwater quality should be assessed in the target aquifers that will receive injected surface water. Water quality degradation can impact the ASR well and nearby beneficial users with wells in the same aquifer, so water quality monitoring should be implemented to track impacts related to both the ASR well and the nearby receptors. Contaminants can be introduced or mobilized during injection cycles and recovered during recovery cycles. Therefore, monitoring the injection supply water, the recovered water, and water quality within the aquifer is essential. The injected water and groundwater form a mixing zone at the **injection front** that can be tracked through sampling for added or **intrinsic tracers**. Monitoring the injection front can be useful for monitoring water quality impacts (refer to the definitions in the text box).

KEY TERMS

Intrinsic tracers are non-reactive constituents that can be used to track water fate and transport. Constituents should be notably different concentrations or values in either the aquifer or injected water source to be used as a tracer. Common tracers are salts, temperature, and non-reactive minerals or metals.

The **injection front** is the interface where the injected water mixes with the aquifer. Water quality degradation can occur at the injection front due to changes in water geochemistry.

Secondary Monitoring

Monitoring the volume and rate of injected and recovered water is an important consideration to assess project performance. The injection and recovery volume and rate are typically measured at the wellhead. If water quality impacts are known or anticipated in the aquifer or mixing zone then the project proponent may wish to inject more water than is extracted to maintain high-quality water near the well.

Additional Useful Monitoring

Monitoring of parameters related to reductions in streamflow depletion, subsidence, and seawater intrusion can have a range of applicability for ASR projects. Monitoring of these other parameters can be a priority depending on geographic and geologic conditions and the intended benefits of the ASR project. For example, an ASR project stated to provide benefits to seawater intrusion should monitor and report the sodium isocontours obtained from sodium water quality testing. These monitoring approaches are discussed in other methods.

A Step-by-Step Guide to Applying ASR Monitoring Method

Implementation of an appropriate and effective monitoring method for an ASR project includes the following strategies and steps:

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. ASR 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 ASR project and design a monitoring network that can assess and track the risk of potential impacts to beneficial users by 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).
3. **Water quality modeling:** Identify any known or potential water quality or aquifer geochemical conditions that might be affected by ASR operation. Review background geochemical data, review proposed recharge water chemistry compared to local groundwater chemistry, and confirm compatibility. Perform predictive geochemical groundwater modeling scenarios to assess if impacts to groundwater and beneficial users are anticipated. Use the information to adapt the project plan.
4. **Install ASR well:** Install ASR well or retrofit an existing well with ASR infrastructure for pilot testing.
5. **Install monitoring wells:** Install or identify monitoring wells in the aquifer where the ASR well is screened. Wells should be located between the ASR well and supply wells that may be impacted based on predictive groundwater modeling scenarios. Monitoring wells in other aquifers or at different depths in the same aquifer as the ASR well should be considered depending on the degree of hydrogeologic interconnection with the ASR well location and depths/locations of supply wells. Useful considerations, guidelines, and applications for locating monitoring wells at recharge project sites are provided in *Standard guidelines for managed aquifer recharge, ASCE/EWRI 69-19 / American Society of Civil Engineers* (American Society of Civil Engineers, 2020)
6. **Data collection:** Collect background groundwater level and quality data prior to ASR operation. Collecting seasonal data for up to 1 year prior to project implementation is useful for establishing a baseline.
7. **Pilot testing**: Perform ASR pilot testing consisting of injection and recovery cycle monitoring. Pilot testing should be performed at the design injection and recovery rates using water of similar makeup to the planned source for full-scale implementation. Monitor groundwater quality of injected water and recovery water at the wellhead and in monitoring wells close to the ASR well to assess water quality degradation in the aquifer and extracting water. Monitor groundwater levels in monitoring wells to assess changes in levels or gradient caused by injection and extraction that might cause groundwater mounding or surfacing or affect groundwater fate and transport.
8. **Permits:** Permit the project through the Regional Water Quality Control Board. Permits typically require a monitoring and contingency plan be in place for monitoring and addressing effects to beneficial users.
9. **Implement the project:** Full-scale implementation should include source and production groundwater quality sampling, groundwater level monitoring for changes, and measurement of injection and recovery volumes and rates, similar to the process described above for pilot test monitoring. During recharge events, groundwater levels should be collected continuously (at least

daily) using groundwater level transducers to estimate changes in groundwater level and groundwater gradients. Water quality monitoring frequency and analyte lists can be determined in conjunction with the Regional Water Quality Control Board with jurisdiction over the project.

Data and Protocols – Fundamentals

Information/ Data Requirements

ASR monitoring typically consists of measuring changes in groundwater levels, monitoring groundwater quality impacts, and monitoring recharge rates/volumes. Table 1 provides an example list of monitoring parameters that can be used in reporting and understanding the effects of a project in a quantifiable way over time. The fundamental monitoring methods for ASR projects include the following:

- Aquifer groundwater level monitoring using wells or piezometers installed in the saturated zone for evaluating changes in groundwater levels and gradients due to recharge operations. Groundwater levels are measured manually using electrical sounders and automatically using pressure transducers lowered into and/or installed in the monitoring wells and piezometers. Groundwater level monitoring protocols are provided in the Department of Water Resources (DWR) Best Management Practices (BMP) 1 Monitoring Protocols Standards and Sites (DWR, 2016). The use of dataloggers in association with pressure transducers allows automated collection and storage of water level measurements at frequent intervals.
- Water quality sampling of source water extracted water, and monitoring wells to evaluate water quality changes due to injection and extraction cycles. Water quality monitoring guidelines are provided in the ASR General Order (SWRCB, 2012a). Recharge may result in blending and reactions of source water with ambient groundwater and aquifer sediment, potentially mobilizing chemical constituents. Water samples can be collected directly from a tap at the wellhead during injection and extraction cycles. Groundwater quality monitoring in dedicated observation wells should follow protocols provided in DWR's BMP 1 Monitoring Protocols Standards and Sties (DWR, 2016).
- Volumes and flow rates of injected and extracted water in the ASR well should be measured using a flow meter installed at the wellhead.

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

Monitoring Reporting	
Total Injection	XXX AF
Total Extraction	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 the ASR, determine any limiting factors on performance, and identify options for improving performance. This assessment also includes evaluating possible increasing concerns, as operations continue, for causing unreasonable harm to nearby land or beneficial water uses and if/how operations can be better managed to avoid significant risks.
2. **Prepare reports and manage data:** 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 can be uploaded to the DWR system annually and progress on project implementation and monitoring can be provided in Annual Reports. If the project is associated with

a GSP, the annual project summary should be provided in the Annual Reports, and a full project performance assessment should be provided in the 5-Year Assessment Report.

Data Standards

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

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

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

Key Protocols

The following protocols should be followed for required monitoring:

- The SWRCB ASR General Order provides many of the practical and regulatory considerations for ASR projects in California (SWRCB, 2012a).
- Standard groundwater level measurement and groundwater quality monitoring protocols are described in DWR's BMP 1 (DWR, 2016).
- Guidelines for establishing monitoring networks and resolving data gaps to reduce uncertainty are provided in DWR's BMP 2 Monitoring Networks and Identification of Data Gaps (DWR, 2016).
- State Water Resources Control Board – 2018. Water Recycling Criteria. Title 22, Division 4, Chapter 3, California Code of Regulations.
- The Division of Drinking Water will need to permit ASR projects intended to provide drinking water supply.
- Technical and reporting standards are included in California Water Code (CWC) §352 *et seq*.