
*The following is an excerpt from the Groundwater Dependent Ecosystems Monitoring Method [MM-10]*

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

# Groundwater Dependent Ecosystems Monitoring Method

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|---|---|
| **Project / Action Type** | Monitoring for general impacts, effects, and connections between the groundwater dependent ecosystems (GDEs) and the sustainability indicators. |
| **Similar / Related Project Types** | Interconnected Surface Water |
| **Primary Metric** | *Note that not all will apply. Metrics will be region and GDE classification type specific.*<br>GDE type.<br>GDE area of cover.<br>Groundwater levels.<br>Surface water stage.<br>Surface water flow rates.<br>Applicable groundwater/surface water quality constituents. |
| **Measurement Unit** | Vegetation vigor and plant surveys (root zone index, wetland species).<br>GDE area of cover in acres.<br>Groundwater levels measured in feet in a consistent vertical datum.<br>Surface water levels in feet (stage/depth, channel elevation).<br>Surface water flow rate in cubic feet per second (streamflow).<br>Concentration or measurement of applicable water quality constituents (typically mg/L), may include nitrate, electrical conductivity, or other constituents of concern. |
| **Beneficial User** | *The GDEs are themselves the beneficial users*<br>Freshwater replenishment to surface waters (FRSH) |

## Groundwater Dependent Ecosystem Monitoring

Monitoring networks should be designed to detect potential adverse impacts to beneficial uses, including GDEs. Establishing a monitoring network and monitoring method relies on first understanding and mapping the GDEs likely to be impacted by a project. First and foremost, a conceptual groundwater model is needed to document the conceptual understanding of the location of GDEs and inferred interactions between ecosystems and groundwater. If a numerical groundwater model is available, it should be used to simulate the project's impact on groundwater levels in and around GDEs, based on the conceptual groundwater model developed, thereby focusing monitoring to a specific area.

Monitoring GDEs over time to assess changes in response to changing groundwater conditions is based on a combination of existing available data, field observations, and management criteria specific to the region, and specific types of GDEs. Monitoring of GDEs generally falls under the sustainability indicators measurable thresholds. Methods for monitoring GDEs should be specific to the needs and interconnectivity of different GDEs to the water source. Surface water and groundwater can both play a vital role in GDE maintenance and monitoring of both may be required.

## A Step-by-Step Guide to Applying Groundwater Dependent Ecosystem Monitoring Method

A step-by-step guide to apply the monitoring method for assessing project impacts on GDEs is provided below. The steps have been summarized into a method framework or flow chart as shown in Figure 1.

Although each of the main steps should be followed, there are multiple options available within each step. For example, Step 2 provides several options for desktop analysis and field surveys. Local conditions and available data will dictate the selection of the appropriate options.

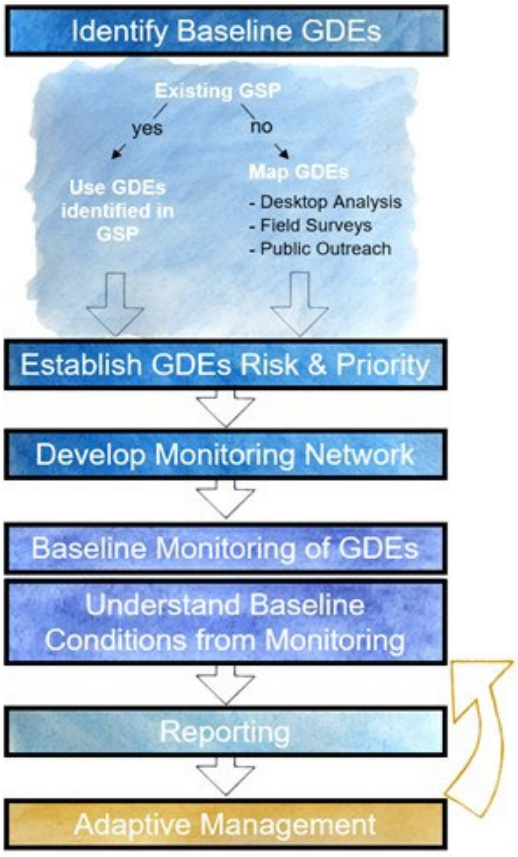


***Figure 1. Groundwater Dependent Ecosystem Method framework***

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. Projects which have an impact on groundwater dependent ecosystems may require a Safety Plan to address these and other potential safety concerns.
2. **Identify baseline GDEs -** Identify terrestrial, riparian, and aquatic GDEs and determine a baseline understanding of groundwater and surface water relationships.
    a. Have potential or confirmed GDEs been identified in the area likely to be influenced by the project? If, so use this as a starting point for identifying GDEs.
    b. Map GDEs and characterize GDE condition, using a combination of appropriate options listed below–

    *Desktop analysis, e.g.:*

    - **Hydrogeological analysis** to identify conditions where GDEs are most likely to exist. This requires a conceptual understanding of flow between aquifers, and areas of groundwater recharge and discharge. For example, spring-based GDEs occurring at geological contacts, or spring-based and baseflow GDEs supported by the discharge of groundwater along fault lines. Use surface water and groundwater elevation data to understand the nature of groundwater and surface water connectivity, and depth to water to understand terrestrial GDE access to groundwater.
    - **Aerial photographs** can be analyzed to map vegetation communities, geology, and geomorphology (see Figure 2). These data are used to determine likely groundwater dependance and need ground-truthing to clarify areas of uncertainty. Unsupervised interpretation, using image analysis software, can translate data from satellites or aircraft into maps of vegetation type, leaf area index, vegetation condition and/or evapotranspiration. The correlation of a GDE with specific geomorphic, hydrogeological, or hydrological conditions that have groundwater dependence in one area may be used to infer the presence and distribution of those GDEs over larger spatial scales.
    - **Geographic information systems (GIS) modeling** by overlaying and linking existing spatial datasets, including topographic, soil and geological maps, depth to groundwater, vegetation maps, ground or airborne geophysical surveys, aerial photography and/or satellite imagery etc. GIS analyses are best used when there is good information on specific characteristics of existing GDEs, which can then be extrapolated to infer the location of similar GDEs in other areas.
    - **Remote sensing analysis.** Remotely sensed data collected by satellites or aircraft record the radiation absorbed or emitted by the earth surface (including by vegetation). The radiation sensed is processed using different algorithms to develop images of the earth surface that highlight particular landscape features, such as areas of open water, moist or dry soil, presence or absence of vegetation, leaf-area index, and plant productivity. A long-standing and commonly used algorithm is the Normalized Difference Vegetation Index, which uses the ratio of red and infrared bandwidths to produce an Vegetation Index value between -1 and +1 for each pixel of the area being sensed.

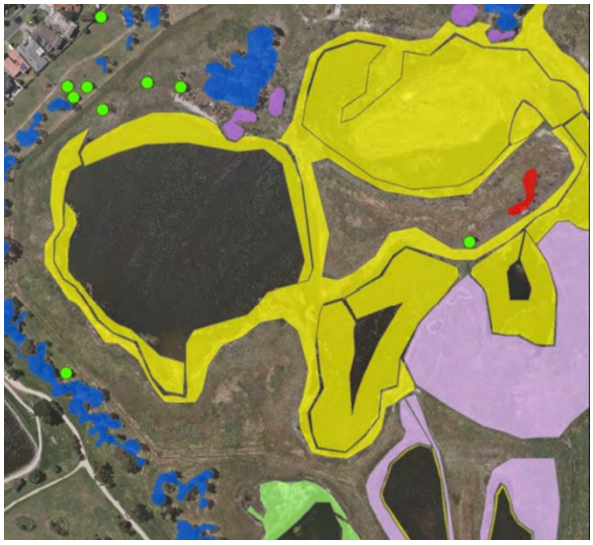

Figure 2. Example Habitat Zone Mapping (AECOM and GHD, 2018)

**Figure 3. Example of Benthic Monitoring using a Teledyne Oceanscience Z-Boat. (AECOM and GHD, 2018)**

*Field surveys, e.g.:*

- **GDE field observations**. Field confirmation and photographic record of GDE type and health.
- **GDE surface water observations**. Field observations of surface water flow and water depth, bathymetry surveys (see Figure 3) Field measurements of temperature. See Groundwater and Surface Water Interactions Monitoring Method (MM-07) for streamflow gauging.
- **Seepage (or accretion) measurements** – See Groundwater and Surface Water Interactions Monitoring Method (MM-07).
- **Environmental tracers** – See Groundwater and Surface Water Interactions Monitoring Method (MM-07).
- **Artificial tracers** – See Groundwater and Surface Water Interactions Monitoring Method (MM-07).
- **Geophysical surveys** – See Groundwater and Surface Water Interactions Monitoring Method (MM-07).
- **Ecological indicators**

*Public outreach and input*

- **Workshops.** Working with the community to understand the historical context of the GDE and how the landscape has changed over time.
- **Transparency.** Providing the community with information that is already available to build relationships and support.

3. **Establish GDE risk and priority**
    a. Establish the ecological significance of the GDEs, i.e., is the site considered to be of local, national, or international importance
    b. Assign ecological values to the GDEs
    c. Establish the priority and risk ranking of the GDEs
4. **Develop monitoring network**
    a. Consider GDE risk levels and existing monitoring networks, establish groundwater (shallow and if relevant, deep wells), surface water (flow and depth), ecological (field observations) and climate (temperature, rainfall, evaporation) monitoring networks. Note that new monitoring features may be required to complete the network (see Figure 4 for an example surface water stage monitoring station). 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).

**Figure 4. Example surface water stage (level) monitoring. (AECOM and GHD, 2018)**

5. **Baseline monitoring of GDEs** - Establish the specifics of data collection.
    a. Establish and collect data for relevant monitoring parameters to identify potential impacts to GDEs. Parameters could include:
        - Groundwater levels (measured as elevations and depth below natural ground surface)
        - Groundwater quality (e.g., salinity, major ions, nutrients, metals)
        - Surface water levels (measured as elevations and depth below measuring point)
        - Surface water quality (e.g., salinity, major ions, nutrients, metals)
        - Climate (rainfall, temperature, evaporation)
    b. Establish monitoring frequency for relevant monitoring parameters to identify potential impacts to GDEs. For example:
        - Groundwater levels – daily
        - Groundwater quality – quarterly
        - Surface water levels– daily
        - Surface water quality– quarterly
        - Climate – as per available NOAA data record
    c. Establish monitoring duration to identify potential impacts to GDEs. For example, monitor baseline conditions at least 2 years prior to project implementation or based on GSP requirements.
6. **Understand baseline conditions from monitoring:** Understand the range of conditions at the end of the baseline period.
    a. Establish baseline conditions and variability based on existing conditions. Is there evidence of declining ground/surface water levels and/or quality in any groundwater monitoring points near the GDEs?
    b. Compare baseline conditions to lowered groundwater level and interconnected surface water.
    c. Estimate degree of dependence of the GDE ecology/fauna on groundwater.
    d. Confirm and describe if there is evidence of declining groundwater and/or surface water levels, quality and/or flow.
    e. Establish performance standards (e.g., triggers or conditions that define acceptability or cause undesirable results, may be outline in a regions GSP)

   f. Establish review frequency to assess performance standards.

7. **Reporting:** Report monitoring data is recommend being reported twice per year.
   a. Establish relevant stakeholders.
   b. Establish data management and sharing arrangements.
   c. Recommend monitoring points to add to the monitoring network.
   d. If project falls within a Groundwater Sustainable Agency, then compare monitoring to the requirements of GDEs laid out in the GSP.
8. **Adaptive management:** Expand or refine monitoring network adaptively, as needed.
   a. Review and update monitoring requirements.
   b. Consider relevant impact verification measures.
   c. Consider relevant risk analysis techniques.
   d. Review and update mitigation options assessment, implementation, and validation.

## Data and Protocol - Fundamentals

GDE mapping is the first step in identifying the GDEs and understanding their relationship to groundwater sustainability indicators. There are several digital mapping methods available based on the region. The GDE Pulse web app developed by The Nature Conservancy provides data on long-term temporal trends of vegetation vigor based on remote sensing. Aerial photos from the U.S. Department of Agriculture provide free high resolution aerial photography through the National Agriculture Imagery Program. However, digital data should be confirmed with (potentially higher resolution and more reliable) local data. Additional information and cross-referencing can be made using local resource documents or habitat specific monitoring plans prepared by other agencies. Field visits should be conducted in the area likely to be impacted by a groundwater project to confirm remote sensing requirements in assessing GDE locations, GDE type, and current conditions. Public comment and community input also is a key component that needs to be considered. Site specific GDE information should be integrated with available groundwater level (and where relevant, quality) data near the GDEs to assess the relationship between groundwater conditions and GDEs.

Groundwater levels are the primary metric for the groundwater water source for GDEs because they are one of the controlling factors in supporting rooting depths for vegetation based GDEs, and the primary measure used to assess groundwater flow regimes and potential ecosystem connectivity. Remote sensing of vegetation locations for GDEs can be compared over time and areas assessed compared to groundwater levels. However, since aquatic GDEs depend, in part, to groundwater contributions from interconnected surface water, streamflow/stage is another metric, particularly in the summer and fall months before the significant rainfall months.

Similarly, water quality (ground and surface) may be a useful metric for some GDEs, particularly in:

- Assessing surface water quality in the context of vegetation condition.
- Assessing interaction between surface water and groundwater.
- Conceptualizing the hydrological regime.
- Assessing temporal water quality variability and establishing baseline conditions.

### Data Standards

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

### Key Protocols

The key protocols for GDEs monitoring are:

- GDE Observations: Locating and identifying ecosystems that are potentially groundwater dependent based on physical parameters such as depth to water table, soils, and vegetation type.

Assessing primary productivity, water relations and/or condition of vegetation communities using remotely sensed images to infer use of groundwater (Richardson et al, 2011b).

- Groundwater Levels: Department of Water Resources (DWR) Best Management Practice (BMP) 1 Monitoring Protocols Standards and Sites (DWR, 2016) - describes protocols for measuring groundwater extraction, groundwater levels, and streamflows to assist in the establishment of consistent data collection procedures and processes.
- Water Quality: USGS National Field Manual for the Collection of Water Quality Data (Wilde, 2005) and DWR's BMP 1 Monitoring Protocols Standards and Sites (DWR, 2016).
- Streamflow and Depth: USGS Water Supply Paper 2175, Volume 1 – Measurement of Stage Discharge and Volume 2 – Computation of Discharge. This method is currently being used by both the USGS and DWR for existing streamflow monitoring throughout the State and DWR's BMP 1 Monitoring Protocols Standards and Sites (DWR, 2016). Utilizing computer models for streamflow and depth analysis is a secondary approach given the potential for limited real-time data. For additional information see Groundwater and Surface Water Interactions Monitoring Method (MM-07).

The regional GSP Regulations include specific requirements to identify GDEs and the protocols that should be considered when determining whether groundwater conditions are having potential effects on beneficial uses and users. It is acknowledged that each basin is unique, that not all projects fall under a GSP, and adaptations to the monitoring plan may be needed to meet project specific needs.