Hydrogeology and ASR Design

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Today there are many choices for the design and operation of an aquifer storage and recovery (ASR) facility, since such facilities can serve a variety of needs. An ASR facility has the capability to recharge, store, and recover all or a portion of the source water recharged regardless of the recharge method. It might consist of shallow or deep infiltration basins, vadose zone wells, direct injection wells, wells that can both inject and recover water, or a combination thereof.

Evaluating Land and Water

The selection of a facility initially is driven by the available source water, available or needed land, and the planned end use of the water. What is the source water? It may be wastewater effluent, seasonal surface water, vested or certificated water rights, or another water source. Once identified, its chemistry must be evaluated to determine if it will need pretreatment or if the quality is adequate for the project method.

Next, how much land is needed and of what type? A vadose zone, injection, or dual-use (recharge/recovery) well in an urban setting has a significantly smaller footprint than an infiltration basin; however, the unit land cost may be much higher. How will the facility design be incorporated into the available land or vice versa? Is the land undeveloped or has it been disturbed?

Finally, what is the end use of the stored water—what type of recharge/recovery cycle will be needed? How long will the water be stored before it is recovered, and how will it be accounted for until it is recovered? Answering these questions will guide the project design and budget through the next phases of project planning. A life-cycle cost analysis is also useful to determine the appropriate recharge method and its application to a specific project and water source.

Now the Hydrogeology

No matter what type of recharge method is decided upon, all ASR projects require characterization of the hydrogeologic conditions in the vicinity of the project site. This begins with identifying the land use and land owners, and any existing wells and their use, proximity to the project site, water source, conveyance options, and water quality.

Baseline hydrologic data are critical to predict future impacts from the project. These data should include a water-level-elevation contour map showing direction of groundwater flow and hydraulic gradient, and determination of storage capacity or transit capacity of the vadose zone. Are water levels at surrounding wells increasing, decreasing, or both? Areas of subsidence should be mapped relative to the project location. Baseline groundwater chemistry data should be collected if they are not already available, and constructing one or more project monitoring wells may be warranted.

Data Needs

Depending on the type of recharge method to be used, additional hydrogeologic data may be needed. Infiltration basin facilities require a detailed investigation of the surficial soils and vadose zone. Soil samples should be analyzed for lithologic characteristics such as grain size, distribution, intrinsic permeability, residual moisture content, and pore-water chemistry. A similar investigation should be conducted in the vadose zone through use of soil borings strategically located to represent site conditions for the project area. The goal of this investigation is to identify positive attributes of the soils and vadose zone, such as high porosity and permeability that would be conducive for a particular recharge method, as well as negative attributes such as the presence of subsurface impermeable layers or

Aerial view of the Vidler Recharge Facility, a privately-owned project in western Arizona that contains over 460 acres of surface infiltration basins. Photo: Kenney Aerial contaminants. Site-specific tests using infiltrometers should be conducted, as well as field-scale infiltration tests to determine initial and long-term infiltration rates for use as facility-design parameters. Borehole percolation tests may also be used to develop a vertical hydraulic conductivity profile of the vadose zone.

Initial infiltration rates for recharge through basins in Arizona have been found to range from about one foot per day to more than 12 feet per day, depending on site conditions. However, these rates may decrease by one-half to two-thirds during actual facility operations. Initial testing and site characterization are important for determining project feasibility, but only long-term project operations provide true infiltration rates that determine the project's viability.

Sampling and chemical analysis of pore water and soils can identify potential constituents that, once the facility is in operation, could migrate due to water infiltration. For example, nitrates are known to occur in pore water of undeveloped arid soils. Operation of an ASR facility might mobilize them, resulting in a concentration of nitrates at the groundwater interface. Knowing the potential for migration of a constituent prior to facility construction is beneficial so that other alternatives, such as use of a different recharge method, can be considered.

Test to Target

Similar data should be collected to identify target injection zones for vadose zone wells, if that recharge method is chosen. For direct injection and dual-use wells, standard hydrogeologic characterization of the aquifer system is needed. This includes a lithologic description of the drill cuttings and a full suite of geophysical logs. In addition, aquifer testing and determination of hydraulic properties, including transmissivity, storage coefficients, and hydraulic conductivity should be conducted once the well is constructed and the aquifer water chemistry analyzed. Monitor wells should be installed as part of this effort, initially to determine the viability of the aquifer system, subsequently for use during the testing of the injection/dual-use well, and finally during facility operations to monitor water level and chemistry, and as a regulatory point of compliance if needed. Regardless of the recharge method used, the receiving aquifer system needs to be understood so that the potential effects of recharge to the system can be discerned.

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Plan on Maintenance

Maintenance and operational issues for ASR facilities include mechanical plugging such as air entrainment, conveyance system dry-ups or maintenance, and other issues including biofouling. Biofouling is an all-encompassing term that pertains to all organisms that can cause a reduction of infiltration or injection rates. Correct identification of biofouling agents is imperative in order to devise an effective treatment plan. Biofouling can also occur in the form of algal mats or clogging layers in basins. Maintenance of affected facilities would include dry-outs and scarification of the basins to remove clogging materials, and well development or redevelopment for vadose zone, injection, and dual-use wells.

Careful thought and planning are necessary to develop a successful ASR project. Source water characteristics and amount and type of available land guide the initial design and type of recharge facility to be constructed. But hydrogeologic characterization ultimately determines the feasibility of the project, the design criteria, and the project's long-term viability.

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