

Water Available For Replenishment

Appendix D: Water Available for Replenishment Methods of Replenishment Guidance

Table of Contents

Overview	3
Considerations for All Replenishment Projects	4
Season, Rate, and Volume of Available Water	4
Reliability of Available Water	5
Water Quality	5
Location and Need for Conveyance	5
Groundwater Replenishment and Water Rights.....	5
Effect on Sustainable Management of the Groundwater Basin	6
In-lieu Replenishment Methods	8
Conjunctive Management.....	8
Direct Replenishment Methods.....	8
Recharge Basins.....	8
Example Project.....	9
Flooding Agricultural Lands.....	9
Example Project.....	10
In-stream and Canal Replenishment.....	10
Example Project.....	10
Injection Methods.....	11
Example Projects	11
References and Sources of Additional Information.....	12

Overview

Groundwater recharge (or replenishment) is the mechanism by which surface water moves from the overlying land surface and into the aquifer below. Replenishment can be accomplished when surface water moves through the topsoil and subsurface, or through injection of water directly into the aquifer through wells. Natural replenishment occurs from precipitation falling on the land surface, from infiltration of water stored in lakes and streams, and from groundwater underflow into the basin. Natural replenishment occurs largely without intentional actions by man.

Managed groundwater replenishment means intentionally placing or keeping more groundwater in the aquifer than what would otherwise occur naturally. Managed groundwater replenishment can be achieved directly through a variety of actions, such as:

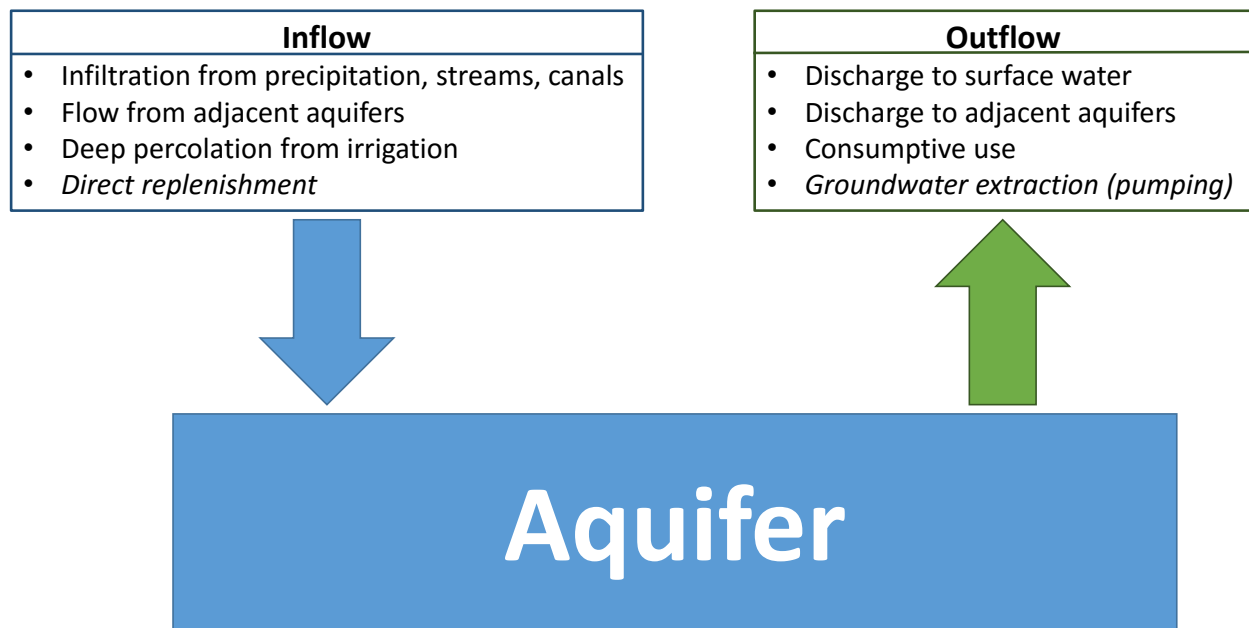
- Construction of spreading basins or injection wells.
- Managed releases of water down natural channels or man-made canals.
- Intentional flooding of agricultural lands to increase seepage into underlying aquifers.

Managed groundwater replenishment can also occur indirectly through in-lieu recharge, by providing surface water to users who would normally use groundwater, thereby leaving more groundwater in place. Groundwater replenishment can also occur as a secondary benefit of some actions, including deep percolation from applied irrigation water and water placed into unlined conveyance canals.

Replenishment methods can be generally divided into two main categories: *direct replenishment* and *indirect* or *in-lieu* replenishment. These methods affect different components of a groundwater budget. Figure D-MR1 illustrates the two components of a simplified groundwater budget: inflow to the aquifer and outflow from the aquifer.

The considerations described in this appendix will be the responsibility of the GSAs, including water agencies and their consultants, who can best evaluate the optimal civil and hydrogeological aspects of recharge projects for their GSAs.

Figure D-MR1. Basic Groundwater Budget



Direct replenishment projects affect the recharge, or aquifer inflow component, while in-lieu replenishment projects affect the pumping, or outflow component.

Managed groundwater replenishment often requires the implementation of two integrated projects; one project to make water available (supply) and another project to get water into the aquifer (recharge). Appendix C provides roadmaps for several different methods of making water available for groundwater replenishment. This appendix provides background, information, and sources of additional information on different methods of managed groundwater replenishment.

Considerations for All Replenishment Projects

While each groundwater replenishment project is unique, some issues are common to all or most replenishment projects. Review of common issues and understanding how they relate to a specific project is an important part of initial planning, and may help narrow replenishment options under consideration.

Season, Rate, and Volume of Available Water

When water is available is an important consideration for selecting a replenishment method. Water may be available only during certain times or years. For example, surface water is more likely to be available for replenishment during months when existing demands are low and during years of above average precipitation. This may make coupling available surface water with in-lieu recharge projects challenging. The volume and rate of available water are also important considerations for selecting the type of replenishment project. When large volumes of water are made available over a short period of time, the selected replenishment method must be appropriately sized to accommodate the higher volume and rate of flow.

Method Guidance: Method of Replenishment

Under certain situations, the combination of large volumes of water at a high rate indicates the need for temporary surface storage before groundwater replenishment. Surface storage projects can be used to store large volumes of water, when it is available, and then release the water when it can be used for groundwater replenishment. Surface storage projects can be integrated with existing groundwater uses to create or expand conjunctive management programs to improve overall water supply reliability. Smaller surface storage projects could be combined with injection wells, spreading basins, or other active recharge projects to facilitate replenishment.

Reliability of Available Water

Reliability has many different meanings and measures in water resources. In the context of groundwater replenishment, the replenishment project reliability is determined by clarifying when, where, and how much water will be available for replenishment. Different methods of making water available will provide water for replenishment with varying degrees of reliability. Surface water methods that rely on precipitation and runoff may provide water on a schedule that is less reliable than recycled water or desalination. The reliability of the water made available for replenishment should be considered in the selection of a replenishment method.

Water Quality

The quality of water made available for replenishment can help focus the preferred options available for replenishment. As described in Appendix C, Title 22 can govern the potential uses of recycled municipal wastewater based on the level of treatment. All replenishment projects should consider the quality of replenishment water to prevent the introduction of pollutants into aquifers.

Location and Need for Conveyance

Although California has a comprehensive distribution of State, regional, and local conveyance infrastructure, the location where water is available frequently does not coincide with the location of where it can or needs to be replenished. Replenishment projects may need to develop additional conveyance capacity to move water between where it is available and where it is needed for replenishment. Opportunities exist to utilize existing conveyance infrastructure or even natural waterways to convey replenishment water, and in some locations, to directly replenish aquifers. Conveyance of replenishment water through existing facilities may need to be accommodated within the governance structures and rules for such facilities as mentioned in Appendix C-WT, Water Transfers.

Groundwater Replenishment and Water Rights

A groundwater replenishment project may need to include a water rights analysis. In most circumstances, a water right is needed to divert, store, or directly use surface water for replenishment projects. California water law allows the diversion of surface water to underground storage; however, diverting water into underground storage is typically not a beneficial use of water (an exception is replenishment to prevent saline intrusion into freshwater aquifers).

Storage in underground aquifers is a method of diversion, not a beneficial use. A water rights analysis must extend beyond storing the water underground to show the ultimate beneficial use of the stored water. For many areas, replenishment water will be extracted in the future for purposes such as municipal and industrial supply or agricultural irrigation. These purposes are recognized beneficial uses under California water right law and represent the end use of replenished water. A water rights analysis

Method Guidance: Method of Replenishment

that demonstrates diversion to underground storage and withdrawal and use of replenished water would meet current legal requirements.

The State Water Resources Control Board recently initiated a new program to expedite the review and approval process for water right permits for groundwater recharge. In November of 2015, Governor Brown issued Executive Order B-36-15, which required the State Water Board to prioritize temporary water right permits for groundwater recharge and storage to enhance the ability of local or State agencies to capture high precipitation events for local recharge. This temporary program is intended to help the State Water Board gather the information needed to develop a comprehensive, permanent program for permitting groundwater recharge of high flows. Temporary permits under this program can be obtained significantly faster than traditional water right permits because of the expedited review and approval process, and the CEQA exemption provided by the executive order. Temporary permits allow diversions for a period of 180 days. This makes the permits useful for investigating pilot projects, but not as a long-term reliable method for making water available for replenishment.

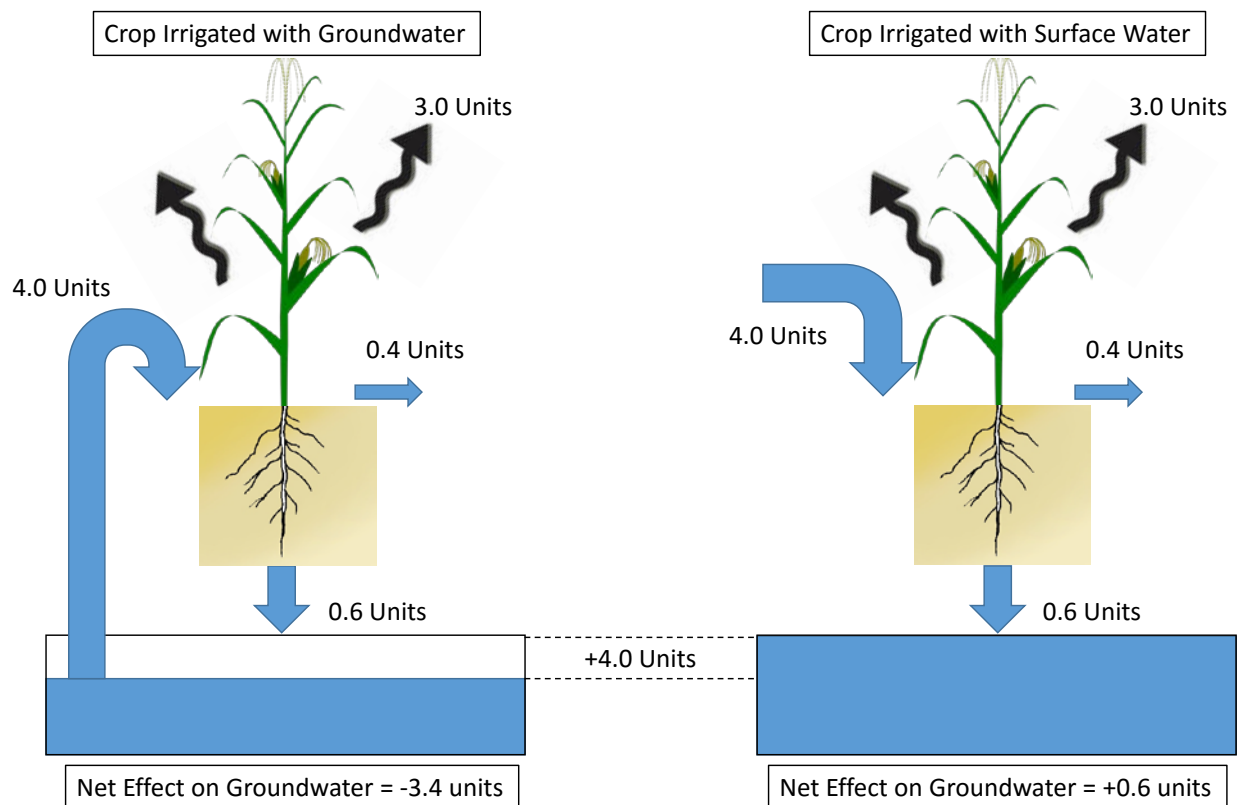
A second legal issue for replenished groundwater relates to the rights to water stored underground. Legal precedence in California has established that a water right holder who uses surface water or imports surface water for groundwater recharge, under circumstances where that water would not otherwise recharge the aquifer, holds the rights to that groundwater (see *City of Los Angeles v. City of San Fernando* (1975) 14 Cal. 3d 199 and *City of Santa Maria v. Adam* (2012) 211 Cal. App. 4th 266, 301, cert. denied (2013) 134 S. Ct.). The ownership issue of replenished groundwater may need to be addressed locally at the groundwater sustainability agency (GSA) level when developing groundwater sustainability plans (GSPs).

Effect on Sustainable Management of the Groundwater Basin

Key considerations for any replenishment project are the potential effects of proposed management actions on achieving the sustainability goal for the basin, ensuring the basin is operated within its sustainable yield. A technical evaluation must be performed to quantify the frequency, timing, and quantity of water replenished by the project, and the resulting effect of these actions on the annual groundwater budget and sustainable groundwater management as defined and required under the Sustainable Groundwater Management Act (California Water Code Section 10721).

In-lieu recharge may result in replenishment on a one-for-one basis in some basins where a unit of water delivered in-lieu of groundwater pumping is a unit of water remaining in the aquifer. The key to understanding how in-lieu recharge affects the water budget is to understand what is currently occurring without the in-lieu replenishment project versus what will occur with the project — a “without” vs. “with” analysis. Figure D-MR2 illustrates how replacing groundwater with water from another source can affect the groundwater budget.

Figure D-MR2. Effect of In-lieu Recharge on Groundwater Budget



In this example, the only change is replacing the source of water used for irrigation. Other actions, such as the volume of water applied (4.0 units), surface water return flow (0.4 units), evapotranspiration of the crop (3.0 units), and deep percolation (0.6 units) remain unchanged. The net effect on the groundwater water budget (+4.0 units) is the change from the net effect before the project (-3.4 units) to the net effect after the project (+0.6 units).

The effect of other projects, such as aquifer storage and recovery (ASR) wells, can be measured as the water injected through the well. The volume of water placed in spreading basins can typically be measured, and water levels within the basin tracked to estimate infiltration rates. There will also be losses from spreading basins as water evaporates from the water or soil surface before infiltrating into underlying aquifers.

Quantifying replenishment from flooding agricultural fields may be more challenging. It may be possible to measure water applied to fields through existing irrigation infrastructure; however, most fields are not closed systems and not all applied water will remain on the field. Agricultural fields provide existing areas for additional groundwater replenishment, but are not designed specifically for this purpose. Information on soil properties, aquifer properties, and infiltration rates may not be known. There also will be losses through evaporation, and a portion of the water applied may remain in the root zone and be consumed by plants through evapotranspiration.

In-stream replenishment projects, discussed in the “In-stream and Canal Replenishment” section of this appendix, may be the most challenging to quantify effects on a groundwater budget. Stream-aquifer

interaction is a function of numerous variables that spatially and temporally vary. For example, the difference in water levels in the stream and surrounding aquifer is one factor that affects the rate of infiltration through a streambed. Water levels are rarely constant and can change significantly during certain times of the year.

In-lieu Replenishment Methods

In-lieu replenishment can be defined as providing water to meet a demand that would otherwise be met from groundwater extraction. In-lieu replenishment changes a basin's groundwater budget by reducing the volume of groundwater pumping. One of the challenges of in-lieu replenishment projects is aligning surface water availability with demands. The Mediterranean climate in California, combined with significant demands for water during summer months, frequently results in little to no water being available during periods when it is most needed. Short-term storm events can provide large volumes of replenishment water; however, these flows are predominantly available during winter months when demands are typically low. In-lieu recharge may require an ability to store water when it is available for delivery during periods of high demand. Water made available through methods such as recycling, desalination, and even conservation, may make water available when groundwater pumping is occurring to meet demands.

Conjunctive Management

The coordinated management of both surface water and groundwater resources to meet demands is *conjunctive management*. Conjunctive management is practiced in varying degrees throughout California, and in many areas conjunctive management is similar to in-lieu recharge, based on the availability of surface water. Infrastructure, agreements, and programs are already in place to facilitate conjunctive management in many areas of the state.

In areas where infrastructure and surface water availability allow for conjunctive management, in-lieu recharge can still occur, even when replenishment water is not available every year or is less reliable than desired. In other areas, infrastructure may need to be expanded to help facilitate conjunctive management and expand in-lieu recharge. Conjunctive management will likely be a key component of achieving groundwater sustainability for many GSAs.

Direct Replenishment Methods

Direct replenishment can be defined as water placed or spread on the land surface, or injected into an aquifer through a well for the purpose of aquifer replenishment. The method of direct replenishment may be determined based on the method of making water available for replenishment, by local conditions and resources that may favor the development of one replenishment method over the other, or a combination of both.

Recharge Basins

Recharge basins are frequently used to recharge unconfined aquifers. Water is spread over the surface of a basin or pond in order to increase the quantity of water infiltrating into the ground. Recharge basins operate by concentrating large volumes of infiltrating water on the land surface to provide opportunities for recharge over larger areas and for longer periods of time than what would otherwise occur. The infiltration capacity of recharge basins is initially high, and then as recharge progresses, the infiltration rate decreases as a result of surface clogging by fine sediments and biological growth in the uppermost

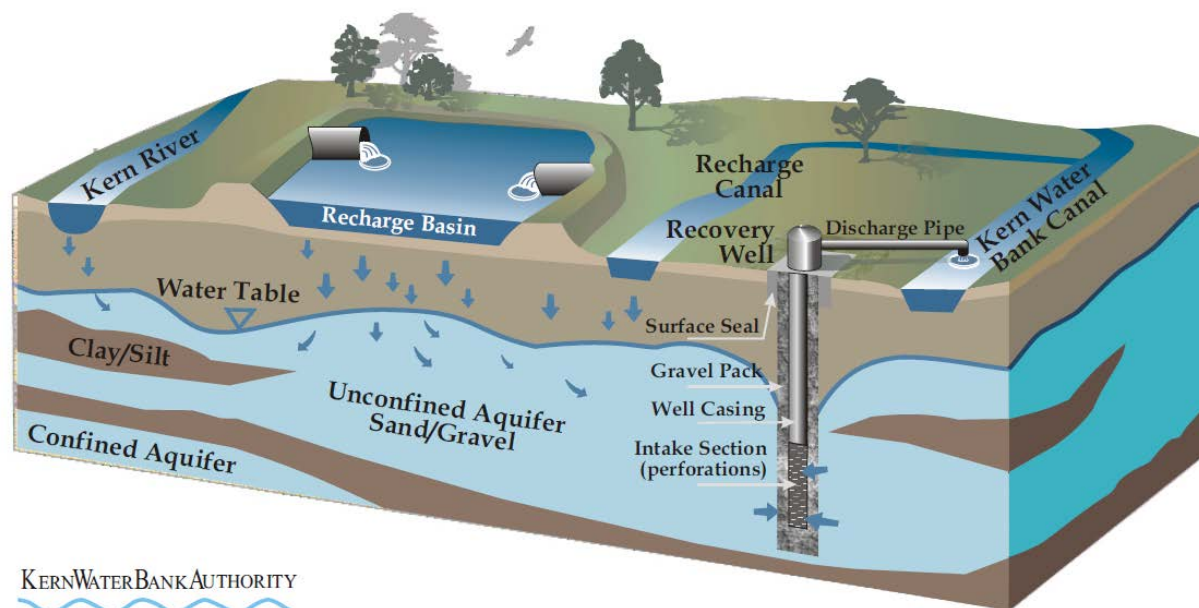
layer of the soil. It has been found that the operation of recharge basins with alternating flooding and drying-out periods maintains the best infiltration rates. Additionally, spreading basins or infiltration ponds can improve water quality through treatment of water held in the basin or ponds, and by filtration and bioremediation of the water as it moves through the soil column.

Example Project

The Kern Water Bank is operated by the Kern Water Bank Authority, a Joint Powers Authority comprised of six member agencies, covering an area of nearly 30 square miles in the southern San Joaquin Valley, near Bakersfield. The Kern Water Bank contains approximately 7,000 acres of recharge ponds with the capacity to recharge up to 72,000 acre-feet per month. Surface water from the State Water Project, Central Valley Project, and the Kern River is used for active recharge through the spreading basins. While the bank primarily relies on spreading basins for recharge, recharge also occurs through the Kern River and canals used in the conveyance of water within the bank (see Figure D-MR3).

Additional information on the Kern Water Bank is available at <http://www.kwb.org/>.

Figure D-MR3: Recharge and Recovery at Kern Water Bank



Flooding Agricultural Lands

Recent research conducted by the University of California, Davis (UCD), in collaboration with local agencies, delineates the flooding of agricultural lands with stormwater runoff or other high winter flows for the purpose of groundwater replenishment (University of California, Davis 2016). Pilot projects in Siskiyou, Yolo, and Stanislaus counties employed flooding of fields and orchards in 2016 to increase groundwater replenishment.

To assist in identifying areas where recharge may be more efficient, researchers at the UCD California Soils Resources Laboratory and UC Agriculture and Natural Resources reviewed and compiled available data on soils, topography, and crop type to understand agricultural lands with relatively more potential

Method Guidance: Method of Replenishment

for replenishment across the state. This research led to the development of the Soil Agricultural Groundwater Banking Index (SAGBI) and an associated map application (available at <http://casoilresource.lawr.ucdavis.edu/sagbi/>). The SAGBI identifies the suitability of soils for additional on-farm groundwater recharge in California, and identified 3.6 million acres of agricultural land, statewide, as having excellent or good potential for groundwater recharge (Green et. al 2015).

Example Project

On February 3, 2016, the State Water Board issued a temporary permit for the diversion and use of water to the Yolo County Flood Control and Water Conservation District (YCFCWCD) to divert up to 40,000 acre-feet from Cache Creek in Yolo County for groundwater recharge and later irrigation use (State Water Resources Control Board 2016). The water was to be diverted from January through April of 2016, when permit conditions that adequately protected both senior water rights and the environment were met. Groundwater recharge was to occur through the combination of unlined canals and on up to 50,000 acres of agricultural lands.

YCFCWCD was able to divert approximately 11,000 acre-feet during the period of February 4 through April 15. This water was diverted into their canal system to recharge underlying aquifers experiencing steady decline in groundwater levels, since 2011, resulting from the ongoing drought.

In-stream and Canal Replenishment

Canals and stream channels are also used as a method for applying water to the land surface to increase recharge. Diverting water outside of the irrigation season into unlined canals can supplement groundwater recharge if canal seepage reaches the underlying aquifers. In some areas of California, water management agencies release water from reservoirs into stream channels to enhance recharge while also providing or improving aquatic habitat. Some streams and rivers in southern California have been modified through the construction of levees, berms, and inflatable rubber dams to divert water from the stream channel into off-stream spreading basins and detention ponds, and to extend retention times within the stream channel to improve infiltration. It is relevant to mention that floodplain restoration and other similar projects can help replenishment groundwater without necessarily requiring new instream flow requirements or water rights application, and would provide multiple benefits over the long term.

Example Project

The Santa Clara Valley Water District (SCVWD) is the groundwater management agency for the Santa Clara and Llagas subbasins in Santa Clara County. SCVWD helps manage the county's diverse water supplies, including locally developed and managed water, imported water from the Sacramento-San Joaquin Delta through both the CVP and SWP, and recycled water. Managed recharge of groundwater basins with both local and imported water supplies and in-lieu recharge are important components in SCVWD's strategy to maximize conjunctive use.

SCVWD conducts in-stream recharge operations along approximately 110 miles of stream channel in 30 creeks (Santa Clara Valley Water District 2012). In-stream recharge contributes over 60,000 acre-feet of recharge per year, or approximately two-thirds of SCVWD's managed recharge activities. SCVWD uses both local and imported water supplies for direct recharge. In addition to in-stream recharge, SCVWD's recharge projects include more than 390 acres of off-stream recharge ponds. More information is available in SCVWD's 2012 Groundwater Management Plan.

Injection Methods

The most common injection method for groundwater replenishment in California involves the use of ASR wells. *ASR wells* are groundwater wells that can be used to both inject and extract water from an aquifer. ASR wells and injection methods are typically used to replenish confined aquifers where overlying restrictive soils (aquitards) impede replenishment from direct application of water to the land surface. ASR wells may be more desirable in urban areas where the land available for the construction of spreading basins is limited. ASR wells are typically more expensive to construct and operate than spreading basins, and are limited by both injection rates and water quality. Therefore, ASR wells may not be economically feasible for capturing large volumes of water available over short periods of time. ASR wells may be more effective when combined with a consistent water supply, such as recycled water. Water injected into aquifers must meet stricter water quality standards to prevent aquifer contamination; therefore, the water must typically undergo some level of treatment prior to injection. Injected water must also meet stringent water quality constraints to maintain injection rates and avoid clogging the wells. Prior to injection, many ASR projects treat surface water to drinking water standards. Permitting of ASR wells by Regional Water Quality Control Boards was streamlined in September of 2012 when the State Water Board adopted general waste discharge requirements for ASR wells that inject treated drinking water into aquifers (State Water Resources Control Board 2012).

Example Projects

The Monterey Peninsula Water Management District operates four ASR wells to divert and inject excess winter flows from the Carmel River into the Seaside Groundwater Basin. Initial project investigations began approximately 20 years ago and resulted in the development of two project phases that included two ASR wells each. Phase 1 of the project includes a maximum annual diversion of approximately 2,400 acre-feet with an average annual yield of approximately 920 acre-feet. The more recently completed Phase 2 is designed to store up to 2,900 acre-feet per year with an expected average annual yield of approximately 1,050 acre-feet. More information can be found on the Monterey Peninsula Water Management District website at: <http://www.mpwmd.net/water-supply/aquifer-storage-recovery/>.

References and Sources of Additional Information

Green et. al. 2015. "Soil Suitability Index Identifies Potential Areas for Groundwater Banking on Agricultural Lands." *California Agriculture*, Volume 69, number 2. Viewed online at:

<http://casoilresource.lawr.ucdavis.edu/sagbi/>.

RMC Water and Environment 2015. *Creating an Opportunity: Groundwater Recharge Through Winter Flooding of Agricultural Land in the San Joaquin Valley*, prepared for California Water Foundation, 105 pages.

Santa Clara Valley Water District 2012. *Groundwater Management Plan*, available at:

<http://valleywater.org/Services/Groundwater.aspx>.

State Water Resources Control Board 2012. State Water Resources Control Board Resolution 2012-0046, Approve and initial study/mitigated negative declaration and adopt proposed general waste/discharge requirements for aquifer storage and recovery projects that inject drinking water into groundwater.

State Water Resources Control Board 2016. Temporary Permit 21365, Application T032581, viewed online at:

http://www.waterboards.ca.gov/water_issues/programs/ewrims/temppermit/docs/t032581.pdf.

University of California, Davis 2016. Viewed online at: <http://dahlke.ucdavis.edu/research/groundwater-banking/>.