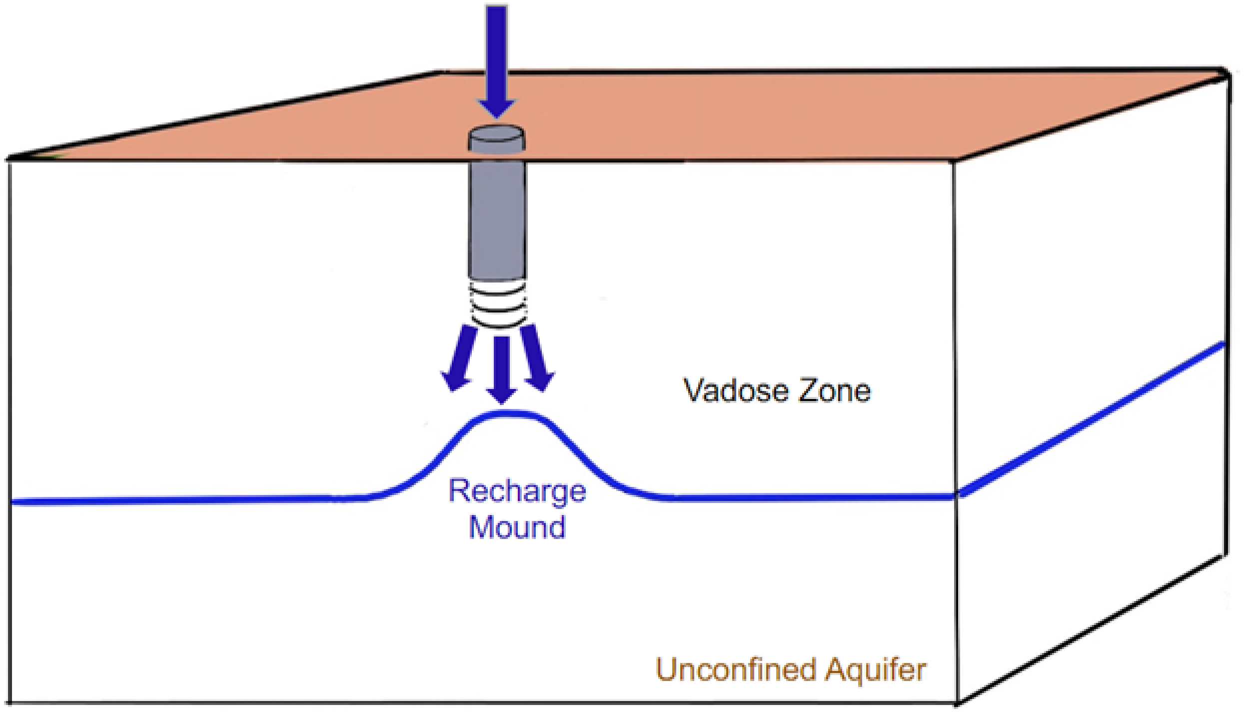
Introduction

Dry wells are gravity-fed excavated pits, typically large diameter (up to 72-inch diameter or more), lined with perforated casing, and backfilled with gravel or stone (see figure below). Dry wells penetrate layers of impermeable soil with poor infiltration rates to reach more permeable layers of soil, allowing for more rapid infiltration of water. Dry wells may be proposed in places where space is at a premium and where there are impermeable surface soils. Urban settings where infiltration basins are too big may be ideal for dry wells. Historically they have been used in conjunction with low-impact development practices to reduce the harmful effects that traditional stormwater management practices have had on the aquatic ecosystem (Pi, Ashoor, and Washburn, undated). They are being used more and more for managed aquifer recharge (MAR) applications, such as augmenting a groundwater supply as the primary function, instead of disposing of stormwater. Dry wells were used on Long Island, NY, to inhibit saltwater intrusion. Care must be taken, however, to ensure the stormwater does not adversely affect the groundwater with contaminants in the form of sediments or chemicals; this can be addressed via pretreatment.



Dry Well

Although the design of a dry well is based on site-specific conditions, most dry wells are 30–100 feet deep and 3–6 feet wide at the surface. Dry wells are often (but not always) lined with perforated casings and can be filled with gravel or rock or left empty. Today, dry wells usually include some form of pretreatment to remove oil, particles, and associated contaminants, reducing the risk of clogging the wells and of creating a conduit to introduce contaminants into a shallow aquifer (E. C. Edwards et al. 2016). Dry well systems are being tested in Northern California using a sedimentation well for pretreatment that filters source water before infiltrating the water through a dry well (Figure 1). Dry wells are prevalent in Utah and Arizona.

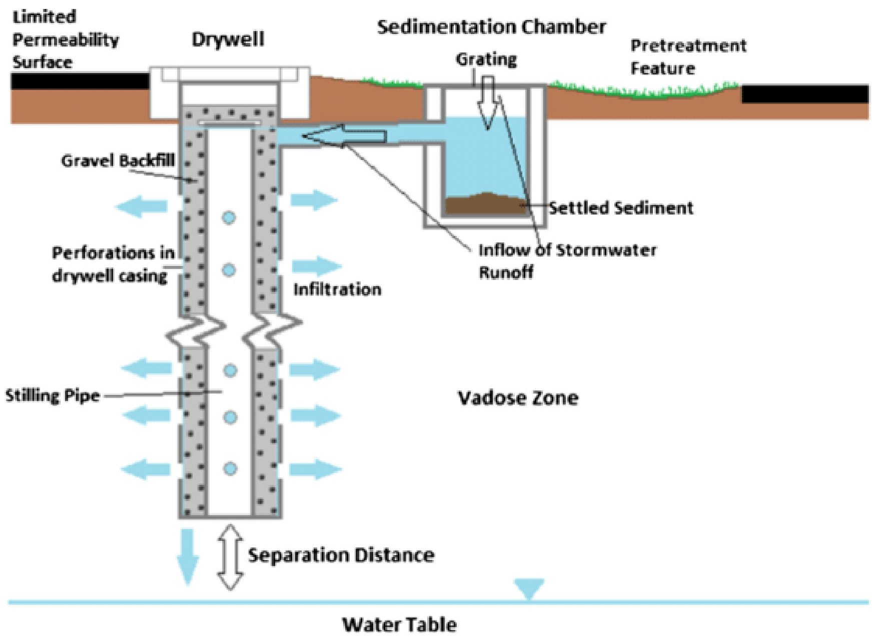


Figure 1. Dry well for stormwater management.

Source: (Edwards et al. 2016) Open Access (Creative Commons — Attribution-Non-Commercial-No Derivatives 4.0 International — CC BY-NC-ND 4.0)

Applicability

Dry wells are applicable in any situation where it is desirable to infiltrate source water into the vadose zone and subsequently into the groundwater. Dry wells are an alternative method to enhance recharge by allowing stormwater to bypass low-permeability layers near the surface and facilitating infiltration of stormwater into more permeable units of the subsurface (E. C. Edwards et al. 2016).

Dry wells have been extensively used for indirect potable reuse in the Scottsdale, Arizona, area to recharge regional groundwater aquifers with over 70 billion gallons of advance treated purified recycled wastewater since 1988 (and 1.7 billion gallons annually). The dry wells are used in Scottsdale Water Campus to recharge high quality water where the depth to groundwater is shallow, providing a more cost-effective approach than injection wells. Site-specific conditions highly influence whether dry wells are more favorable to other MAR technologies, and in urban settings where space is not readily available, dry wells are particularly well suited. Several of these applications include new developments, green streets, and urban retrofits.

Advantages

Dry well systems have the following advantages:

- Gravity flow dry wells are typically 30–100 feet deep and can be installed at a comparatively low cost when compared to injection wells or other technologies (for example, an ASR well that may extend hundreds (up to thousands) of feet in depth, such as the deepest Des Moines Water Works aquifer storage and recovery (ASR) well in Ankeny, Iowa, that extends more than 2,500 feet deep).
- The footprint is generally very small, often a 6-foot diameter manhole at the surface that looks like a common storm drain manhole. The small footprint allows for construction in tight spaces, including built-out urban areas. The equipment and materials required to construct a dry well are common and readily available in the construction industry.
- Construction time for a gravity flow dry well is relatively rapid—a matter of days vs. weeks or months.
- Recharge credits are possible for a private landowner. A water replenishment district (WRD) or utility will receive the benefit for other MAR technologies.
- Construction costs are typically far less than direct injection well technologies.

Limitations

Dry wells systems have the following limitations:

- Dry wells are very difficult, if not impossible, to clean out or rehabilitate once clogged with sediment. High pressure water injection with vacuum extraction may be used to remedy this situation. However, pretreatment of the source water (stormwater) to minimize TSS content is a must.
- Gravity flow dry wells are typically 30–100 feet deep, and it may be difficult to transmit recharge water to a deep aquifer due to intervening low-permeability layers. In contrast, ASR wells may extend up to thousands of feet in depth (as in Iowa, where several ASR wells are more than 2,500 feet deep) and penetrate the aquifer directly.
- Dry well functionality is dependent on the presence of permeable layers of soil that allow for more rapid infiltration of stormwater.
- A dry well cannot be pumped to extract groundwater. It is for infiltration only.

Performance

Use of dry well MAR technology is site-specific, and since the infiltration capacity of a gravity flow dry well is mainly dependent on the surrounding soils, knowing the infiltration characteristics of the soil is critical in determining whether a dry well is suitable for MAR at the site. Percolation (perc) tests or a dry well pilot test may be performed to evaluate the infiltration rate of the near-surface soil conditions for planning and design purposes. Infiltration studies at Fort Irwin, California, have led to the development of a modeling component for evaluating dry well recharge (Drywell Examples (pc-progress.com)

There are several factors that must be considered when assessing the effectiveness of a potential site for recharge. These include, but are not limited to, the properties of the surface and subsurface materials, topography, water conveyance infrastructure, and water availability (Goebel and Knight 2021).

A geologic assessment must be considered for suitability of infiltration at the site. Emerging technologies such as towed transient electromagnetic methods (tTEM), a surface geophysical imaging technique, have made subsurface investigation across large swaths of land much more viable. Assessment technologies might include, but are not limited to, the following methods: tTEM, AEM––airborne electromagnetic surveying, ERT––electrical resistivity tomography, CPT–cone penetrometer testing, and geotechnical drilling.

Initial data from several recent pilot projects in California indicate that a flow rate of 300–500 gpm (1.3 acre-feet/day) is a realistic recharge rate (E. C. Edwards et al. 2016). Dry wells can also be used to return water to aquifers: a single dry well can transmit up to 5 acre-feet of water per year to underlying aquifers, equivalent to the water needs of about 10 households (E. Edwards, Washburn, and Lock 2017).

Dry year and wet year recharge was estimated at 770 acre-feet/year and 8,700 acre-feet/year, respectively, based on a 2005 study examining the groundwater recharge impact of 3,763 dry wells that were installed in a growing Arizona city to drain 1,400 acres of stormwater retention basins (Graf 2015). The predevelopment groundwater recharge was 191 acre-feet of water per year, while the post development recharge through the dry wells was estimated at 2,100–3,100 acre-feet in an average rain year, demonstrating that the dry wells are a significant source of groundwater recharge.

Regulatory Considerations

The laws that address dry wells are the Clean Water Act, Safe Drinking Water Act (SDWA), and Comprehensive Environmental Response Compensation and Liability Act (CERCLA). The regulatory agencies involved in implementation of a dry well program include, depending on established primacy, the U.S. Environmental Protection Agency (USEPA), state agencies, local governments, and tribal governments.

Dry wells are considered Class V injection wells. The USEPA regulates the construction, operation, permitting, and closure of injection wells, including dry wells, through the Underground Injection Control (UIC) program as required by the SDWA. Many states have primacy or authority to implement and oversee their own UIC programs (Figure 2). For example, Washington and Oregon have well-developed programs where dry wells are used extensively. Otherwise, the USEPA either jointly or directly implements programs in the remaining states.

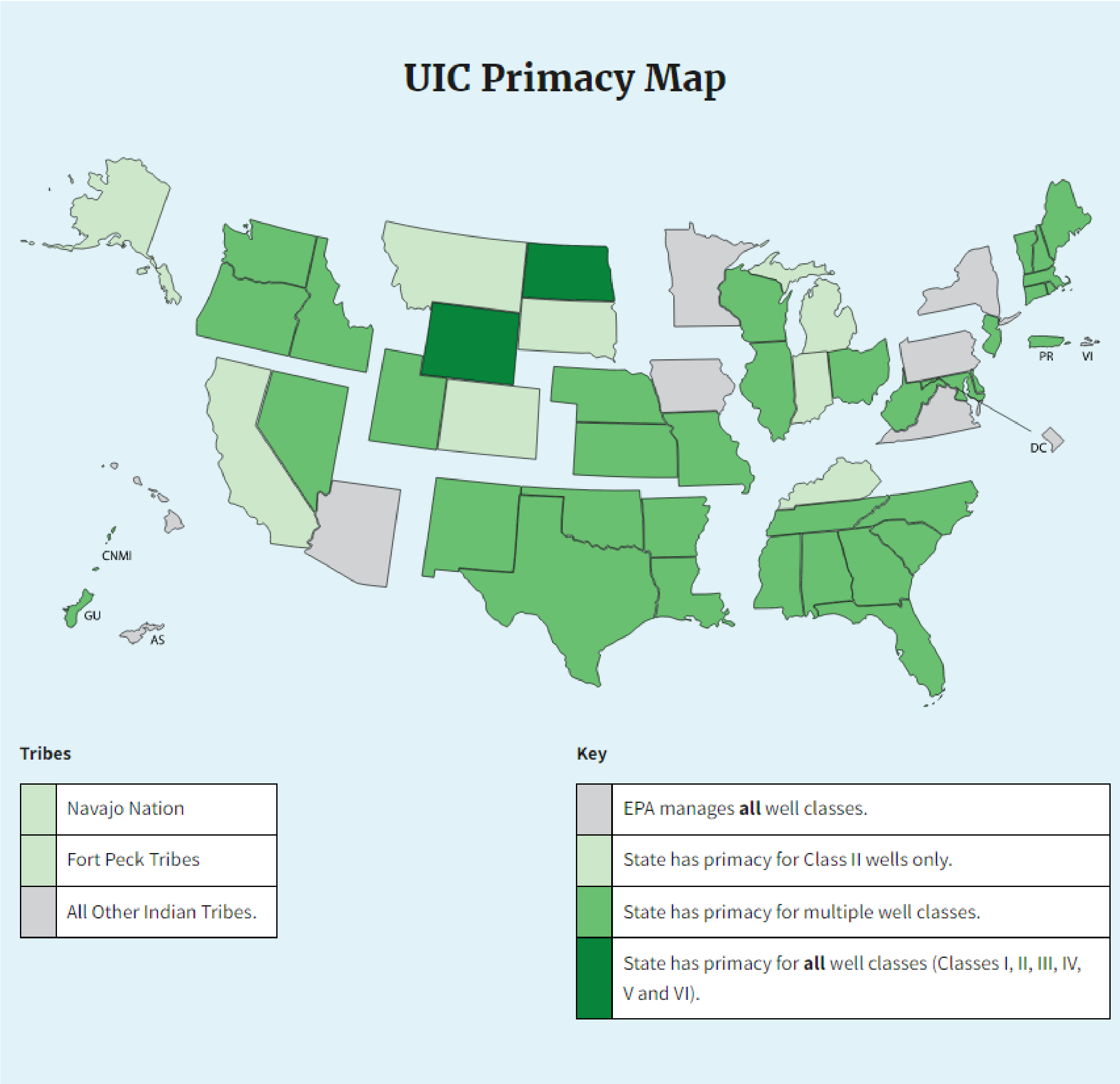


Figure 2. UIC program implementation (tribes are not depicted on map, colors for tribes relate to key—Navajo Nation and Fort Peck Tribes have primacy for Class II wells; USEPA manages all well classes for all other tribes).

Source: USEPA (2022)

Officials may be required to obtain a UIC permit for dry wells, or these wells may be authorized by rule and inventoried, depending on the state where the well is located. Dry wells are required to not endanger the underlying groundwater resource (drinking water), which must be demonstrated to the regulatory agency. As such, dry wells receiving stormwater are preemptively prohibited at some sites where the contaminants may adversely affect groundwater quality, including, for example, in areas involved with vehicle maintenance, airport de-icing activities, or storage or handling of hazardous materials or wastes. Dry wells also may not be used at contaminated sites when the stormwater recharge would increase the mobility of the contaminants at the site (Washington State Department of Ecology 2006). Siting criteria and setback restrictions, in addition to design, construction, operation, and maintenance requirements for dry wells, may also apply in certain jurisdictions.

Although the regulatory and political environment has some influence on differences in dry well programs between states, many of the differences are due to different geologic conditions (site-specific conditions). States with greater amounts of precipitation, high water tables, or bedrock near the ground surface often will not use dry wells extensively, so regulations are less defined. As stated in (Lock, Edwards, and Washburn 2017): “Pennsylvania, New Jersey, Washington, and Hawaii are a few of the others states with dry well regulations and guidelines. In New Jersey, some communities require dry well installation for all new and major remodels related to residential construction. They are typically designed to temporarily store and infiltrate roof runoff. Dry wells in New Jersey are prohibited in industrial or other areas where toxic chemicals might be used. In contrast, in Pennsylvania dry wells are permitted in industrial areas with restrictions, but not along roadways. In Washington, dry wells must be registered and constructed to specifications. The regulations of these states vary with respect to dry well design, use of pretreatment, separation from drinking water sources, distance from the water table, and other factors." Other states, especially those with less rain and deeper water tables, tend to have more detailed regulations because their groundwater resources are less abundant and/or under greater strain.

Stakeholder Considerations

The stakeholders should consider the capital cost as well as long-term maintenance costs of a pretreatment system. A discharge permit and UIC permit may be required, and the requirements for obtaining a permit vary between states. Land ownership and groundwater (and possibly stormwater) rights may need to be considered. Recharge credits are possible for a private landowner, and a water replenishment district or utility will receive the benefit. Potential groundwater contamination is a concern that must be considered. The source water and its compatibility with groundwater and the aquifer must be evaluated for pretreatment needs for dry well applications or potential liability for groundwater cleanup may be a consequence of inappropriate dry well applications.

Lessons Learned

Quantifying the amount of infiltrated water from dry wells that is recharged into the target aquifer is not straightforward due to the complexity of the hydrodynamics of unsaturated flow (Liang, Zhan, and Zhang 2018; Edwards et al. 2022). A robust pretreatment system should be considered in advance of the dry well to address long-term performance (clogging) and to minimize potential groundwater contamination from poor source water quality.

Case Studies (FS-4)

- Turlock, California—Mustang Creek Watershed Dry Well Pilot Study (see Case Study 5.8)
- Texas, New Mexico, Mexico—Hueco Bolson Recharge Project (The Hueco Bolson: An Aquifer at the Crossroads utep.edu).
- Lake Tegel, Berlin, Germany—(Hoffmann and Gunkel 2011) ScienceDirect: Bank filtration in the sandy littoral zone of Lake Tegel (Berlin): Structure and dynamics of the biological active filter zone and clogging processes | Elsevier Enhanced Reader.
- Scottsdale, Arizona—Advanced Water Purification—City of Scottsdale—Recycled Water (City of Scottsdale—Recycled Water (scottsdaleaz.gov). .
- Arizona—Stormwater Vadose Wells—Dry Wells for Stormwater Management: An Evolving Viewpoint | Water Resources Research Center | The University of Arizona.
- Eastern Washington—Washington State Stormwater Vadose Wells—Stormwater Manual for Eastern Washington: Guidance for UIC Wells that Manage Stormwater.
- Oregon—Stormwater Vadose Wells—Oregon's Experience with Dry Wells: The Underground Injection Control Program (ca.gov).
- New Jersey—Dry Wells—NJDEP| Stormwater | NJ Stormwater Best Management Practices Manual
- California—Dry Wells Uses, Regulations, and Guidelines in California and Elsewhere—Dry Wells: Uses, Regulations, and Guidelines in California and Elsewhere.
- Hawaii—Dry Wells—Potential effects of roadside dry wells on groundwater quality on the Island of Hawaii—Assessment using numerical groundwater models (Izuka 2011).
- Cochise County, Arizona—Palominas Flood Control and Recharge Project—Cochise Conservation and Recharge Network (arcgis.com).