AQUIFER STORAGE RECOVERY

This continuing education unit has been created to acquaint the reader with the topic of Aquifer Storage Recovery. The International School of Well Drilling gratefully acknowledges the use of the (edited) material below courtesy of R. David G. Pyne, P.E., President ASR Systems LLC, coiner of the term “aquifer storage recovery” and author of “Groundwater Recharge and Wells-A Guide to Aquifer Storage Recovery.”

Aquifer Storage Recovery (ASR) is the storage of water in a well during times when water is available, and recovery of the water from the same well during times when it is needed. ASR provides a cost-effective solution to many of the world’s water management needs, storing water during times of flood or when water quality is good, and recovering it later during emergencies or times of water shortage, or when water quality from the source may be poor.

Large water volumes are stored deep underground, reducing or eliminating the need to construct large and expensive surface reservoirs. In many cases, the storage zones are aquifers that have experienced long-term declines in water levels due to heavy pumping to meet increasing urban and agricultural water needs. Groundwater levels can then be restored if adequate water is recharged.

The main driving force behind the current rapid implementation of ASR technology around the world is water supply economics. ASR systems can usually meet water management needs at less than half the capital cost of other water supply alternatives. When compared to alternatives requiring
construction of water treatment plants and surface reservoirs to meet increasing peak demands, potential cost savings have been known to exceed 90%.

A second important driving force has been the increased recognition of this technology as being good for the environment, aquatic and terrestrial ecosystems. By reducing or eliminating the need for construction of dams, and by providing reliable water supplies through diversions of flood flows instead of low flows, ASR systems are usually considered to be environmentally friendly.

(Stored water typically forms a large bubble deep underground extending outward radially from the well as far as 1,000 ft. The bubble moves very slowly during the time of water storage, usually less than 10 feet per year.)

Storage zones range in depth from as shallow as about 200 ft. to as deep as 2,700 ft. Groundwater levels in the storage zones range from as much as 30 ft above land surface to more than 900 ft. below land surface.

Natural water quality in the storage zone ranges from fresh, suitable for drinking without treatment, to brackish, including total dissolved solids concentrations up to about 5000 mg/l.

Most sites have one or more natural water quality constituents that are unsuitable for direct potable use except following treatment. Such constituents may include iron, manganese, fluoride, hydrogen sulfide, sulfate, chloride, radium, gross alpha radioactivity, and other elements which are typically displaced by the stored water as the "bubble" is formed underground.
At one site, not currently in operation, ASR was shown to be feasible and highly cost-effective, storing drinking water in an aquifer containing seawater. For most of these sites, it is first necessary to properly develop the storage zone around the well, after which it is possible to recover the same volume as that stored. At a few more challenging sites, water quality, hydraulic or geochemical constraints may limit recovery to somewhat less than the volume stored.

Water is stored deep underground in water-bearing geologic formations, or "aquifers," that may be in sand, clayey sand, sandstone, gravel, limestone, dolomite, glacial drift, basalt and other types of geologic settings.

Stored water displaces the water naturally present in the aquifer, creating a very large bubble around the well. The bubble is usually confined by overlying and underlying geologic formations that do not produce water. However, at several sites, the aquifer is unconfined. Storage volumes in these bubbles range from as small as about 13 million gallons in individual ASR wells, to as much as 2.5 billion gallons or more in large ASR wellfields.

ASR Applications

Most ASR systems provide seasonal water storage, storing water during the wet season and recovering it during the following dry season. Many also use ASR for water banking, storing water during wet years and recovering it years later during extended droughts.

Increasingly, many water managers are constructing ASR systems to ensure reliability during emergencies, whether severe floods, earthquakes, contamination incidents, pipeline breaks, or potential damage due to warfare or sabotage. Increasingly, ASR is being considered for development of Strategic Water Reserves to provide water supply security from terrorism or warfare. Actually, there are at least 22 ASR applications, and others will undoubtedly follow.
Most operating ASR sites are storing treated drinking water. When recovered from storage, this water usually requires only disinfection before being sent out to the water distribution system. In recent years other applications of ASR technology have also begun.

In the Tampa Bay area of Florida, which is an area with tremendous growth in water demand and limited available supplies, treated wastewater is reclaimed and piped to golf courses, parks, gardens and other areas requiring irrigation to reduce the demand for potable water. When the rains begin and irrigation demand ceases, reclaimed water is stored in ASR wells in deep brackish aquifers, from which it is recovered when needed to meet irrigation demands during dry periods. Reclaimed water ASR is therefore beginning to be a booming application of the ASR technology.

A 24” ASR well at West Palm Beach, Florida was initially tested with drinking water from the adjacent water treatment plant and has been retrofitted to recharge and recover partially treated surface water from Clear Lake at rates of 8 million gallons/day. Storage zone is a brackish limestone artesian aquifer at a depth exceeding 1,000 ft.

Several sites are storing untreated groundwater pumped from overlying or underlying aquifers, or from well fields located at great distances from the ASR site. When needed, this water is recovered from the storage zone and combined with whatever flows are then available from the primary water sources, to help meet peak or emergency water demands. In coastal areas subject to salt water intrusion, or other areas subject to contamination or overpumping, ASR is being used to achieve the full water supply benefits of local aquifers, which are then used for water storage more than for water
production. Groundwater ASR is increasingly viewed as a desirable application of ASR technology.

The newest ASR application is for storage of partially treated surface water. Prior to recharge, water is treated sufficiently to ensure that the aquifer does not plug with particulates or organic material, and to ensure that the aquifer is not contaminated. Generally, it is anticipated that the level of treatment will be less than that required for production of drinking water. Stored water is recovered to help meet peak demands for supplemental untreated water, whether for urban needs, ecosystem protection, low streamflow maintenance, agricultural irrigation, industrial water requirements, power plant cooling make-up water, or other needs.

ASR is a unique technology, different than for production wells or injection wells. Understanding ASR technology ensures success almost all situations, whereas misunderstanding the unique aspects of this technology can lead to failure, lost investment and disappointment.

The term "aquifer storage recovery" was coined by David Pyne, P.E. (see first paragraph of text) in 1983, when the first ASR system at Manatee County, Florida, began successful operation. Development of this system had been underway since 1978. Manatee County is completing construction of its third phase of ASR expansion to include four wells with a combined nominal capacity of 10 million gallons/day.

Where is ASR?

ASR systems are known to be operating in the United States, United Kingdom, Canada, Australia, South Africa and Israel. ASR development programs are underway in several other countries, including the Netherlands, New Zealand, Thailand, Taiwan and Kuwait. Operating systems are defined as those for which construction is completed, facilities are fully permitted and in operation.

This is a relatively new technology. In the U. S., the U.S. Geological Survey conducted small tests of well recharge systems beginning in the late 1940s, but none of these test sites were placed into operation. The first ASR well began operation at Wildwood, New Jersey in 1969, and this system is still in operation, having been expanded to four wells. Most subsequent ASR wells have been constructed since 1983, when the Manatee County, Florida, ASR system began operation. Currently, about 69 ASR sites are in operation around the United States, ranging from a single well to 30 wells, with recovery capacities ranging from 0.5 million gallons/day from single wells to 100 million gallons/day from wellfields.

In the planning stages is a very large ASR program for South Florida to restore the Everglades. At such time as this program is completed, it is expected to have over 300 ASR wells storing and recovering water at combined rates of up to 2 billion gallons/day.
Looking at topics of public concern

During the past two years, several public interest groups have expressed concerns regarding whether ASR technology has been adequately proven in Florida. Concerns have focused on whether proposed applications for storage of drinking water, treated surface water, reclaimed water and fresh groundwater in Florida’s brackish aquifers may create unacceptable water quality and environmental problems.

Specifically, concerns have focused on potential leaching of metals such as arsenic, mercury and uranium from the limestone into the recovered water or into the surrounding aquifer; potential contamination of the aquifer with disinfection byproducts (DBPs); potential contamination with pathogenic microbiota such as bacteria, viruses and protozoa; and mixing with surrounding brackish water so that recovery efficiency is reduced to below acceptable levels.

Similarly concerns have been expressed by the United States Geological Survey (USGS) related to the potential for ASR to alter native ground water quality to the extent that it may affect the potential future use of that resource.

Scientific literature is substantial and consistent in showing that, under hydrogeologic conditions prevalent in Florida and almost all other ASR sites nationwide, DBP constituents are reduced or eliminated rapidly through natural processes during ASR storage, if these constituents are present in the recharge water. The principal mechanism for the reduction in the DBP’s is microbial degradation. Several proven approaches are currently utilized at various Florida water treatment plants to control or eliminate the presence of DBPs in the recharge water, if needed. As such, DBP’s should not be an issue for Florida ASR sites.

Metals occur naturally at low concentrations in the limestone of the Floridan aquifer. During ASR storage, these metals may tend to dissolve out of the limestone and create elevated concentrations in the recovered water. Metal concentrations typically decline with time, with distance from the ASR well, and with successive operating cycles. No long-term operating ASR sites in Florida are known to have elevated concentrations of metals such as arsenic, uranium or mercury, although metals data is sparse in many of the data sets.

During initial cycle testing at a new ASR well, elevated concentrations of arsenic may occur at some ASR sites, particularly at those sites recharging treated surface water due to the generally higher oxidation-reduction potential (Eh) of this water. This is of some concern since in January, 2005, drinking water standards for arsenic will decrease from 50 micrograms per liter (µg/l) to 10 µg/l, which is within the range of concentrations observed during initial cycle testing at some Florida ASR sites.

Typically, it is anticipated that after four to eight ASR cycles at the same storage volume, arsenic concentrations should subside to acceptable
levels. This is based upon testing and operational experience at thirteen ASR wellfields in Florida that have been in operation for up to 21 years. There have been no documented instances of water exceeding metal standards having been distributed to the public through drinking water distribution systems from Florida ASR wells.

Pathogenic microbiota are not present in recharge water to ASR wells in Florida, reflecting regulations and policies by Florida Department of Environmental Protection (FDEP) and the SJRWMD to recharge only water that meets drinking water standards for storage in our brackish aquifers. Scientific laboratory investigations and, to a lesser degree, field investigations in Florida, have shown that bacteria, viruses and some protozoa attenuate naturally and rapidly during ASR storage, and under controlled conditions approximating ASR storage. This natural attenuation serves as an additional barrier to protect groundwater quality and public health.

No Florida data are currently available regarding the fate of Cryptosporidium and algal toxins during ASR storage; however, such data are available from sources outside Florida. This is not an issue for recharge water meeting drinking water standards.

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