Aquifer Storage and Recovery – A tool to combat global water scarcity problems

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A growing world population, coupled with intensified water consumption behaviours associated with improved living standards in many parts of the world, have lead to a significant increase in global freshwater withdrawals and water scarcity problems. These developments are forcing the water sector to keep developing more efficient technologies of utilising the available resources in order to meet the growing demand. Aquifer Storage and Recovery (ASR) is an example of such a technological advancement. ASR is a concept where water is stored in geological formations below the earths surface, commonly referred to as aquifers, during times when it is available, thus creating artificial groundwater, which can later be recovered by pumping when it is needed (Pyne 1995). One ASR-cycle typically consists of three phases: Injection, Storage and Recovery.

One possible application for an ASR system, is the long term storage of water for emergency purposes. Hereby, drinking water is stored in the underground over long time periods and recovered when conventional water supply procedures are impaired, for example due to natural disasters, contamination or other unforeseen circumstances. Such systems demand for the consideration of various specialised requirements: High quality freshwater is stored in an aquifer where the prevailing water is of lower quality. The recovered water should fulfill high standards, so that it can be used as drinking water with little to no post-treatment. It is desired to store large amounts of water for an unknown amount of time, and when required, the water should be recovered at rates sufficient to meet the demands of medium to large metropolitan areas.

The main problem with this type of ASR application is that when the water is stored over long time periods, the natural flow of groundwater transports the high quality freshwater away from the location of the wells, where the water is injected and extracted, making it inaccessible for recovery at a later stage. Furthermore, such long time scales allow for a high degree of mixing to take place between the different water types. The primary goal of this work is to understand how the natural groundwater flow influences the performance of ASR systems over time and to develop a procedure for the design and optimisation of such applications. Special focus is directed towards reducing the losses of freshwater and maintaining a good water quality for time periods of up to 10 years. This is done with computer-based simulations of the groundwater flow.

In the design process, the different phases of an ASR cycle are considered separately. The aim is to establish individual design and optimisation procedures for each phase, and to identify which factors can be changed in the individual processes to optimise the design.

The results show that over a 10 year period, substantial amounts of freshwater are transported away from the location of the wells. This water can no longer be recovered from the subsurface and is essentially lost. Hereby, the exact layout of the wells, so how they are situated with respect to one another, influences how much of the water can be regained. When the wells are arranged in an elongated manner, in the direction of groundwater flow, less freshwater is carried away because the surface area against the flow direction is smaller.

When applying different methods to prevent the losses of freshwater, the performance of the system can be increased significantly. A procedure where the water which is transported away from the system is captured and extracted, mixed and re-injected on the other side, has proven to be the most efficient. Without a method to stop water from flowing away, 59% of the freshwater is lost from the system. Through application of an appropriate prevention technique, the losses can be reduced to 32%.

In the design process, the ability of the aquifer to transmit water plays a decisive role. This determines how big the distances between individual wells can be, how much pumping is required to retain the freshwater in the area of the wells, and with which rates the water can be extracted when it is required. At first, some tests were conducted for smaller clusters of 20 to 30 wells. These tests had the intention of understanding how the system reacts to the injection and extraction of water, and to design a basic initial layout. This layout was then arranged in a configuration of rows and columns to create a full sized well-field. A strategy for the prevention of freshwater losses and for the extraction of water was then established for the entire well-field.

For the phase, where water is injected into the ground, it is important to ensure that the freshwater spreads uniformly over the extent of the cluster area and to remove as much groundwater as possible to stop it from mixing with the high quality water. When the water is stored in the aquifer, the most important aspects are to stop the freshwater from flowing away from the wells and so stop new groundwater from flowing towards the wells. When the water is extracted, the main focus of the design should be to maximise the amount of water which is recovered.

References

Pyne, R. D. G. (1995). *Groundwater Recharge and Wells. A Guide to Aquifer Storage and Recovery*. Lewis Publishers, CRC Press. ISBN: 1-56670-097-3.