# ARTIFICIAL RECHARGE AS A METHOD OF WASTEWATER DISPOSAL

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**Summary**

Artificial recharge is a process where liquid is introduced into the sub-surface by anthropogenic means. This procedure can be utilized for the disposal of wastewater or storage and recycling. There are two main techniques for artificially recharging wastewater, surface distribution or injection. Surface spreading techniques require a detention area (basin, pit, pond, canal or weir) situated over a permeable unsaturated zone. The detention area is filled with the recharge liquid, which infiltrates through the unsaturated zone to the saturated zone. Injection techniques comprise a well or bore that can introduce recharge liquid into an aquifer or a permeable region of the vadose zone.

Municipal wastewater, storm water runoff, industrial waste, agricultural runoff and mine tailings can be utilized for artificial recharge. The hydrogeological environment and the type of waste often dictate the method of recharge required. Environmental and reuse requirements for the groundwater will dictate the degree of pretreatment needed before recharge commences. The recharged wastewater may also gain a degree of pretreatment as it passes through the unsaturated and saturated zone.

A number of problems may be encountered in artificial recharge operations such as environmental degradation, health effects, social impacts and in particular clogging of in-situ pore space. In-situ clogging can be caused by physical, biological or chemical processes and remains the greatest impediment to long term sustainability of recharge operations.

Interpretive and predictive models can be used to gauge figures on the controlling parameters and to simulate the effects of artificial recharge operations. Information provided by reliable models is relevant to the financial feasibility and management of recharge facilities. Artificial recharge has a promising future as a method of waste disposal, storage and recycling.

## 1. Introduction

Artificial recharge (AR) is a process by which water is introduced to the unsaturated or saturated zones by anthropogenic means. Water is detained in a surface facility and allowed to infiltrate into the unsaturated zone or injected through a well into the saturated or unsaturated zones. This procedure has a wide range of economic and environmental applications such as water storage for re-usage, environmental waste entrapment, salt water intrusion control, petroleum extraction, subsidence control, liquid waste disposal and liquid waste filtration for reuse. This paper explores the use of AR as a method of wastewater disposal and reuse.

Wastewater recharge can be utilized for the permanent disposal of waste or for treatment and purification of waste for later extraction and reuse. With the increase in worldwide demand for fresh potable water and the increasing production of waste, AR is a promising potential solution for the filtration and storage of wastewater. This is an important progression in establishing sustainable worldwide water management policies and practices in the new millennium.

Historically, AR has been utilized in countries and regions with arid and semi-arid climates. The high evaporation rate in these areas necessitates the development of methods for water storage and reuse that differ from existing surface storage techniques. Countries such as Israel and the United States of America (particularly California) have been world leaders in large-scale AR operations, some of which have been in progress for over a decade. Other countries involved in AR operations are Australia, South Africa, Japan, Germany, Switzerland, Netherlands, Great Britain and Jamaica. Guidelines outlining procedures for AR are available in some countries and states currently conducting recharge operations.

The amount of pretreatment the wastewater requires before recharge, is dependent upon the type of waste, its reuse requirements and the filtration properties of the unsaturated and saturated zones. Developed and developing countries have varying standards for the quality of recharge water and its re-usage. Economic and technical limitations often impede some developing or underdeveloped countries from reaching the same level of pretreatment and post-treatment as that of developed countries. It is assumed that for this paper the type of waste used for recharge will be essentially a fluid or a solid that can be dissolved into a fluid for recharge purposes. The wastewater will contain a combination of dissolved and suspended constituents.



## 2. Background

Regional hydrogeological conditions and project objectives determine the type of recharge operation implemented. Surface spreading and well injection are the two main techniques used for AR. A number of technical, environmental and economic problems may be encountered in AR operations. The greatest technical problem is the clogging of porous media. Physical, chemical and biological processes can cause clogging in the recharge medium on interaction with recharge wastewater. Remedies exist for most physical problems encountered with recharge operations. The various uses of AR are described below:

- **Aquifer storage and recovery** (ASR). Water is recharged by anthropogenic means into the unsaturated/saturated zone and recovered from the aquifer by standard groundwater extraction techniques. This type of recharge is commonly used in a semi-arid environment with seasonal precipitation. Excess surface water, from precipitation, runoff or treated wastewater, can be recharged into the regional aquifer system for later extraction and use when water demand is higher.
- **Permanent waste disposal.** Wastewater that is expensive to treat or intractable is recharged into stable hydrogeological formations for permanent disposal.
- **Wastewater filtration.** Water is recharged through the unsaturated and saturated zones which act as a filtration medium. This is termed ‘soil aquifer treatment’ (SAT). A large proportion of the suspended waste material in the recharge water is trapped within the first 40 cm of the soil profile. A reduction occurs in the inorganic and organic constituents of the wastewater as it passes through the unsaturated zone. The recharged water may be further filtered as it migrates through the saturated

zone. This process is useful for ASR as a method of recharging wastewater, and recycling it for reuse. When waste is destined for disposal this method of recharge can reduce impact on the surrounding environment.

- **Groundwater waste entrapment.** A point source of pollution, which may impact on a regional groundwater system, can be contained by an AR barrier. AR can form a mound in the water table slowing the migration of the pollutant down gradient until appropriate groundwater remediation can take place.
- **Seawater intrusion prevention.** In coastal aquifer systems there is often an interface between the less saline groundwater and seawater. This interface is often characterized by a wedge of seawater underlying less dense, less saline groundwater (Ghyben-Herzberg principle). If groundwater is extracted the seawater can migrate inland causing seawater intrusion. The construction of AR operations along a coastline proximate to this interface can produce a barrier to slow or even prevent seawater intrusion into coastal aquifers.
- **Petroleum extraction.** Water is recharged into petroleum-bearing formations to aid in hydrocarbon extraction. This type of operation is normally performed towards the end of the active life of a petroleum field.
- **Subsidence control.** As groundwater is extracted from porous media, the aquifer will depressurise and pore space will reduce. In areas where excessive groundwater extraction has taken place the land surface may subside. AR of wastewater can be used to reduce land subsidence.

## 3. Methods

Surface spreading and injection are the two main techniques available for AR operations.

### 3.3. Surface Distribution Techniques

Surface distribution techniques are the most common method of AR. Surface spreading involves an entrapment area over a highly permeable vadose zone and aquifer. The area is flooded with the recharge liquid, which is allowed to infiltrate into the ground. A portion of surface material is generally removed from the base of the recharge entrapment area to expose underlying, more permeable material. Surface spreading operations are limited to areas overlying unconfined aquifers or those with a layer of relatively thin (0–10 m), less permeable surface material.

The types of surface spreading operations can be broken into on-stream and off-stream facilities.

#### 3.3.1. On-channel Systems

- **Dams and weirs.** A dam or a weir is constructed in a river or stream, over a highly permeable area in the unsaturated zone. The pooling of water over a recharge zone allows a greater rate of infiltration when compared to a flowing stream. Dams or weirs can be particularly useful in ephemeral streams to maintain a constant head of water recharging the aquifer throughout the year.

- **Canals.** A canal is constructed over permeable surface regions of an aquifer. A recharge canal can serve as an AR facility as well as part of a water distribution system.

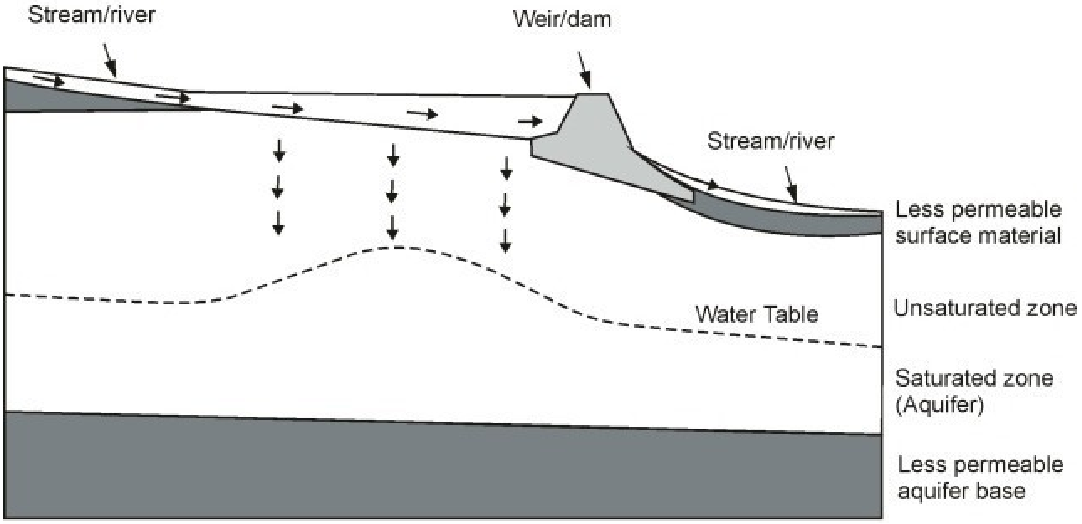


Figure 1. Recharge weir or dam

In-channel systems contain recharge water that is often flowing, which can maintain very fine sediments, such as clays, in suspension. This reduces the amount of clogging in the base of the facility and allows water with a higher turbidity, to be recharged. Natural events causing higher stream discharge or flooding can also clean these facilities.

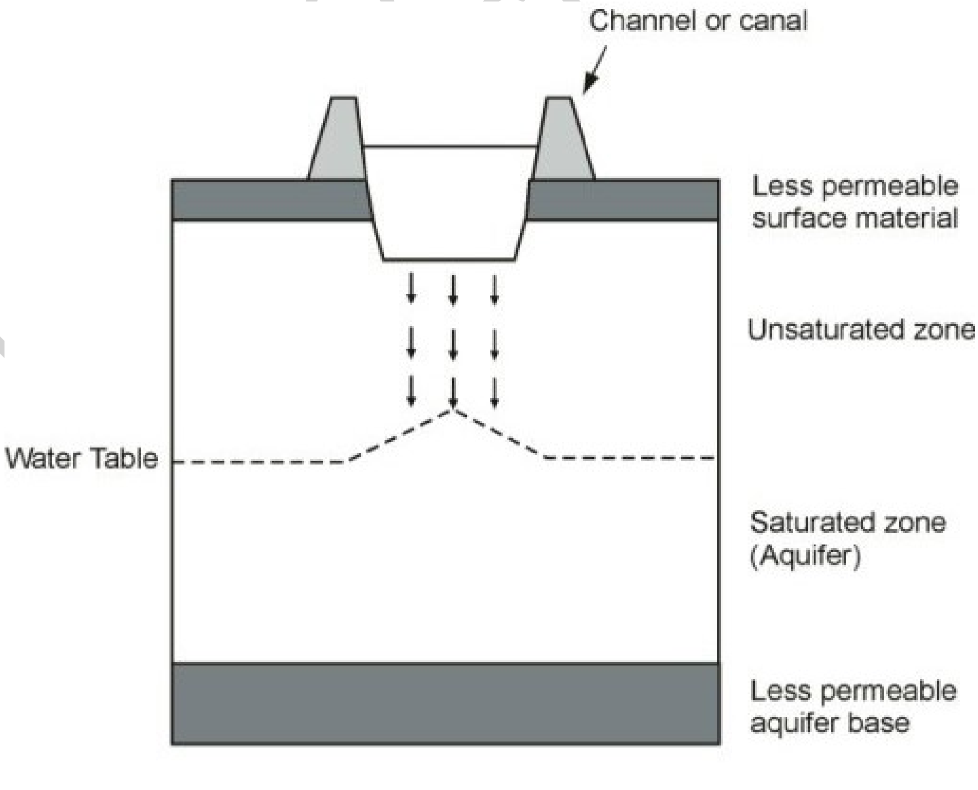


Figure 2. Recharge channel or canal

### 3.3.2. Off-channel Systems

- **Recharge basins/pits/ponds.** A depression is made in the ground, or an area is surrounded by an embankment to create a water detention zone. Construction is usually a combination of shallow excavation which exposes sediments, soil or rocks with a higher permeability, surrounded by an embankment constructed from the excavated material. The larger the detention area over a permeable recharge medium, the greater the volume of potential recharge. A minimum depth of water is required in the recharge facility in order to maintain a sufficient head of water and recharge rate.
- **Recharge trenches.** Recharge trenches work on a similar principle to that of the recharge basins. A long narrow excavation is constructed exposing underlying permeable material. Recharge trenches are usually constructed on a smaller scale than that of large recharge basins and can thus facilitate a simple excavation procedure.

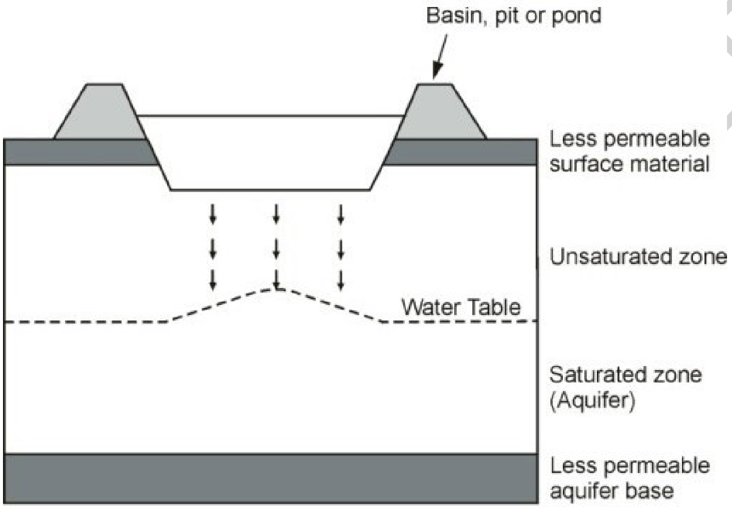


Figure 3. Recharge basin, pit or pond.

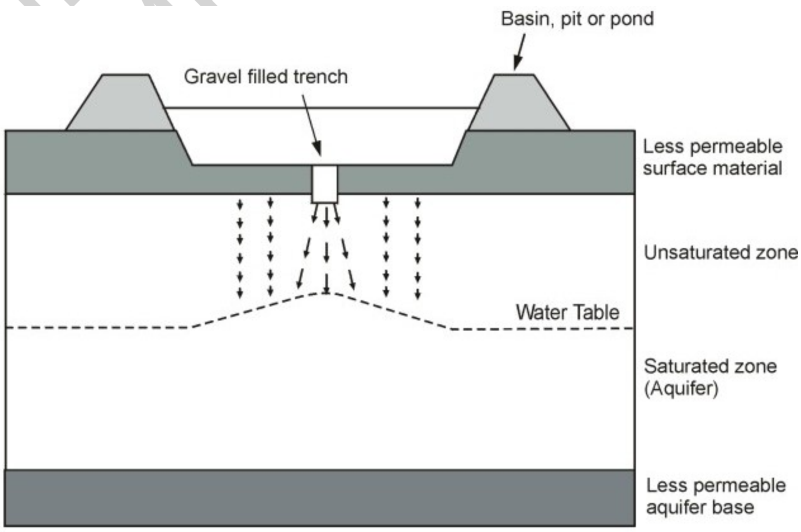


Figure 4. Recharge basin, pit, or pond, with gravel-filled trench to improve recharge rate

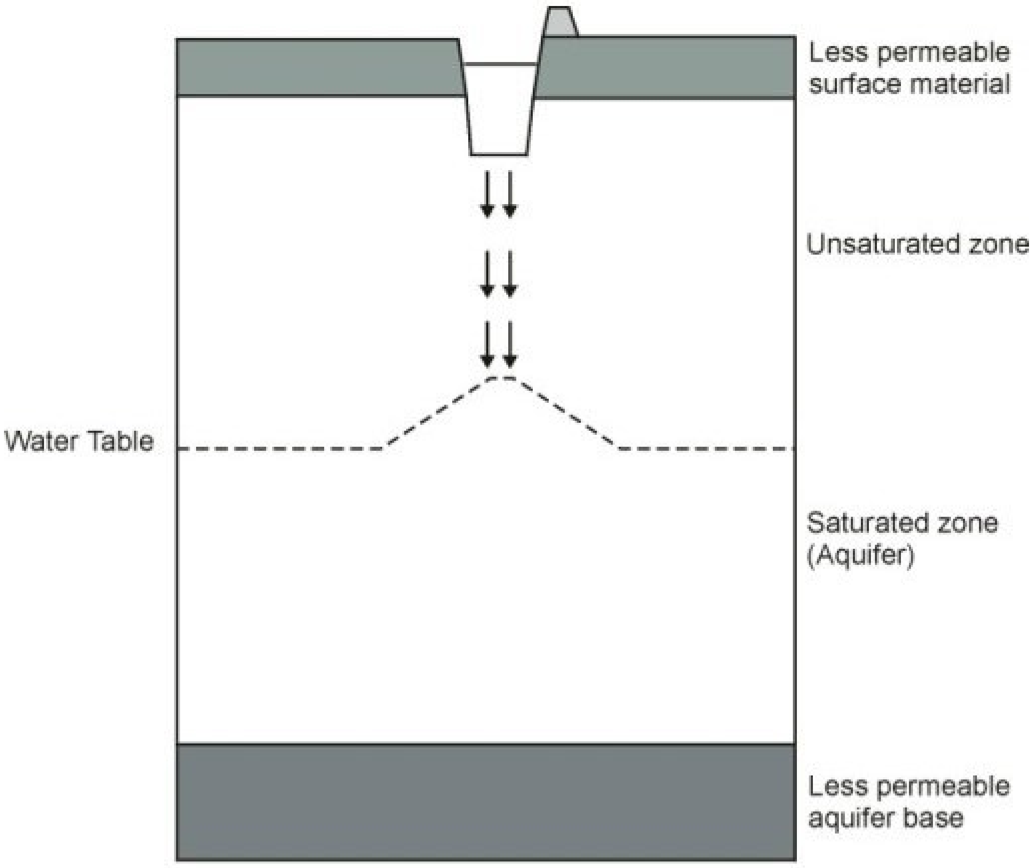


Figure 5. Recharge trench

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**Biographical Sketches**

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