Artificial Groundwater Recharge

WISE WATER MANAGEMENT FOR TOWNS AND CITIES

Ricky Murray

CSIR
ENVIRONMENTEK

Water Research Commission

This booklet is written for those who are involved in water planning, management and supply from large-scale, city supplies to small-scale town and village supplies. It describes artificial groundwater recharge a method of managing water wisely by optimising sub-surface storage. The booklet covers the key issues that affect the success of artificial recharge schemes and provides case studies from Southern Africa.

"Water banking, or storing surplus water in regional aquifers for later use is becoming more common as cities and states seek long-term solutions to the perennial problem of ensuring adequate water supplies, especially for periods of drought"

U.S. Water News Online, 1996.

"The success of the Karkams and Windhoek (artificial recharge) sites can not be overstated. These projects demonstrate at small and large scales a significant improvement in both the quantity and quality (reduced salinity) of water supplies. Potential for reversing declines in groundwater storages, expansion in water supplies, and in increasing security of supply are clearly evident at both sites. The technology has been decisively proven effective at these sites."

Dr Peter Dillon, 2000
CSIRO, Australia and
Chairman, Commission on Managing Aquifer
Recharge, International Association of
Hydrogeologists

"Artificial recharge provides a sustainable opportunity to conserve water and to improve its quality"

Bonvin Kracman,
Chair, International Symposium on Artificial
Recharge of Groundwater, 2002

Photos on front cover:
Top - Injection and abstraction borehole, Adelaide, Australia.
Bottom - Sand filter and pump-house for injection and abstraction borehole, Karkams, South Africa.

WATER RESEARCH COMMISSION

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This booklet draws heavily on the following reports:

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Murray, E C, & Tredoux, G, 2002. Pilot artificial recharge schemes: Testing sustainable water resource development in fractured aquifers. Report to the Water Research Commission, WRC Report No 967/1/02, Pretoria. ISBN 1 86845 883 0

CONTENTS

1. What is artificial recharge?

Artificial recharge is the process of transferring water into an aquifer. The source of the transferred water is usually surface water. Treated wastewater and urban storm runoff are becoming popular sources of artificial recharge water.

Artificial recharge infiltration basin in Atlantis, near Cape Town

Injection borehole in Windhoek, Namibia

2. What is aquifer storage and recovery (ASR)?

ASR is a term used to describe artificial recharge schemes where the injection borehole is also used as an abstraction borehole.

The benefit of ASR schemes:

- Depending on the aquifers hydraulic properties, ASR schemes can provide the most efficient design for recovering injected water.
- The same infrastructure, especially pipelines, can be used for injection and abstraction. This is far cheaper than having the injection and abstraction points far apart.
- This approach makes it possible to store fresh water in a saline aquifer. A "bubble" of fresh water can be created around the point of injection.

The largest ASR scheme is being constructed in Florida, USA. It will have 300 ASR boreholes with a combined injection & recovery capacity of 8 million m^3/d.

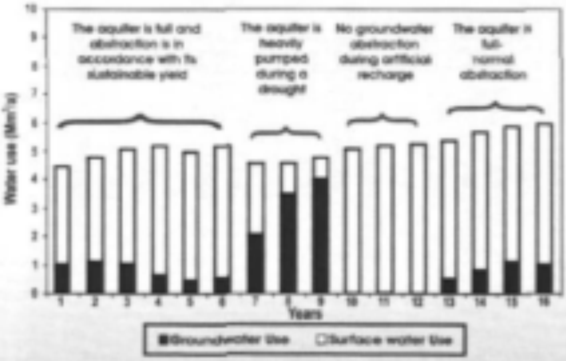
ASR borehole at Bolivar, Australia

3. What is water banking?

Water banking is storing water in an aquifer for security purposes. It usually entails long-term storage with the purpose of providing security during droughts.

Water resource managers find this concept attractive because when their "water bank" is full, they know the volume of their reserves and therefore know how to manage demand. They can also run their dams at greater risk (ie drop the water levels lower than usual) since they have a dependable back up.

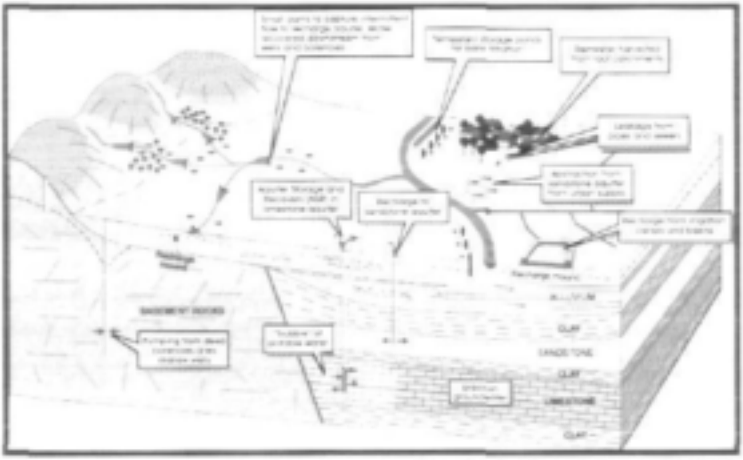
Applying the water banking concept requires modifying the common approach to managing groundwater. Instead of using groundwater according to its sustainable yield, water held in the aquifer may be mined during droughts because it will be rapidly replenished when water for artificial recharge becomes available. Once the "bank" is full (after large-scale artificial recharge), the aquifer is managed according to its sustainable yield until the next drought (see the sketch below).



Aquifer management using the principles of water banking

4. What is Managed Aquifer Recharge (MAR)?

MAR is a term used to incorporate all activities designed to augment aquifer recharge. It includes artificial recharge, ASR, water banking, rainfall harvesting (where this water is used for sub-surface storage) and soil aquifer treatment (the concept of water treatment by infiltration).



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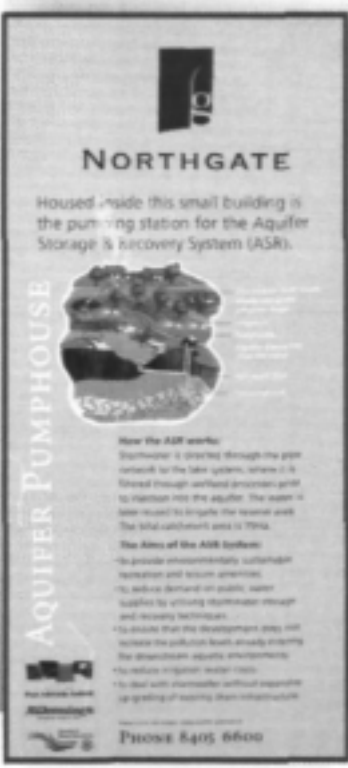
5. INTERNATIONAL EXAMPLES

Country	*Comments / Examples*
Germany	15% of Germany's drinking water is supplied from artificial recharge. River bank filtration and infiltration basins are the most common methods. Trenches (~1 m wide by ~100 m long by ~5 m deep) are gaining popularity. Here infiltration rates of up to 90 $m^3/m^2/day$ are achieved. (Source: Schöttler, 1996).
Finland	Most of Finland's town water supplies come from groundwater of which 32% is artificially recharged. Infiltration rates vary between 0.7 – 2.9 m/day. (Source: Hatva, 1996)
Israel	Borehole injection into a dolomitic aquifer has recharged on average 1.1 million m^3/a over a 23-year period. (Source: Guttman, 1995).
USA	The USA has numerous infiltration and injection schemes. An example of an injection scheme is the limestone aquifer at Peace River in Florida. Here 17 000 m^3/day is injected into 6 boreholes at rates between 20 – 40 L/s. (Source: Pyne, 1995). Another borehole injection example is a sandstone aquifer near Denver, where injection takes place at a rate of 38 L/s. (Source: Lytle, 1994).
Australia	Australia has a number of injection schemes in hard-rock aquifers, including quartzitic aquifers. A 100-year old artificial recharge scheme is in operation at Mt Gambier, where stormwater is infiltrated via ~400 drainage boreholes into a karst aquifer and used for domestic consumption. (Source: Tefler, 1994).



Poster outside the pump house of an injection scheme in Northgate, Australia

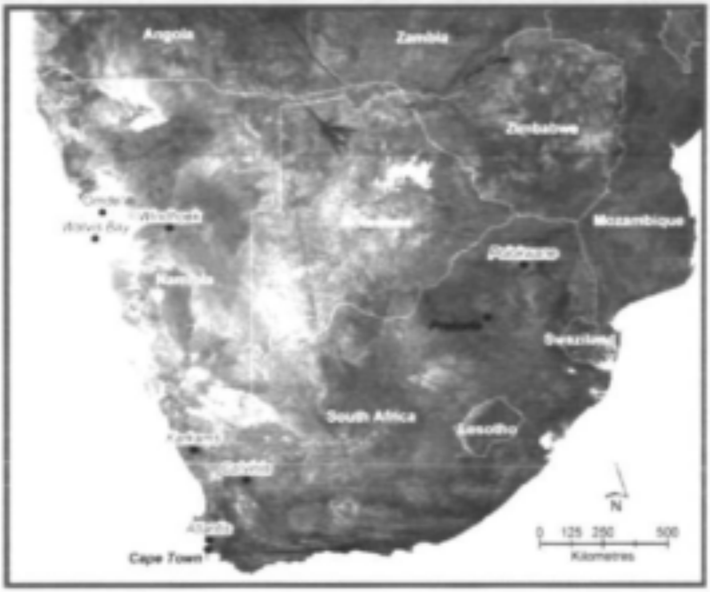
Plans for the Northgate artificial recharge scheme. Urban runoff is collected in wetlands, where the water is treated and then injected into an injection and abstraction borehole. The recovered water is mainly used for irrigation.

6. WHERE IS ARTIFICIAL RECHARGE PRACTICED IN SOUTHERN AFRICA?

There are six artificial recharge sites in Southern Africa that have been studied in depth and few more where feasibility studies have been carried out. In addition to these there are numerous farm dams scattered throughout the region that were built with the purpose of replenishing groundwater. The effectiveness of these dams has never been established.

Site	*Operational Status*
Windhoek	Recently constructed
Atlantis	Over 20 years of operation
Polokwane	Over 10 years of operation
Omdel*	Over 5 years of operation
Karkams	Over 5 years of operation
Calvinia	Recently constructed

* *The Omdel scheme supplies Henties Bay, Swakopmund and Walvis Bay*



Southern Africa's artificial recharge sites.

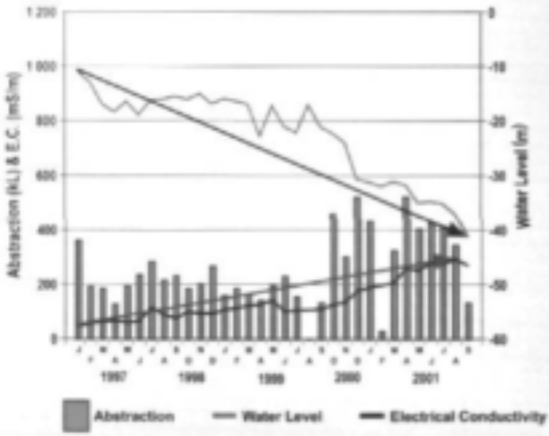
7. Why is artificial recharge gaining popularity?

Water resource managers are increasingly seeing the advantages of integrating surface and groundwater in their desire to conserve water and use it optimally. It also makes sense from an economic and environmental perspective to utilise available sub-surface storage.

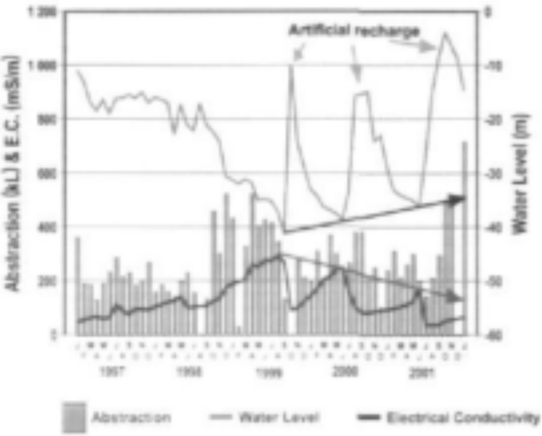
Common uses of artificial recharge are:

- To provide water security during droughts.
- To provide water security during the dry season.
- To provide storage for local or imported surplus surface water.
- To coordinate the operation of surface and groundwater reservoirs.
- To improve the quality of groundwater or to displace saline groundwater by creating a "bubble" of fresh water in the aquifer.
- To combat adverse conditions such as:
  - Progressive lowering of groundwater levels;
  - Saline water intrusion or progressive increasing salinity in the aquifer.
- To provide treatment and storage for reclaimed wastewater for subsequent re-use.
- To reduce or stop land subsidence.

Declining water levels and increasing salinity in a borehole at Karkams before artificial recharge



Reversal of negative trends due to artificial recharge at Karkams



The main purpose of Southern Africa's artificial recharge schemes

Site	*Water security for droughts*	*Water security for the dry season*	*Improve water quality*	*Reuse waste-water*	*Capture storm runoff*	*Prevent saline water intrusion*
Windhoek	✓	✓				
Atlantis		✓		✓	✓	✓
Polokwane				✓		
Omdel	✓				✓	
Karkams		✓	✓			
Calvinia	✓					

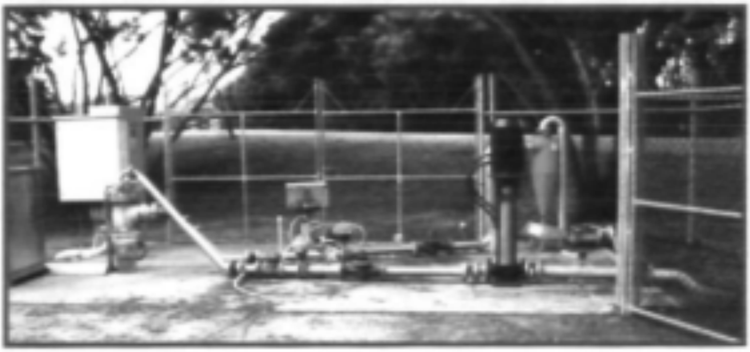
8. How does artificial recharge work?

Artificial recharge requires capturing water, treating it, and transferring it via boreholes, infiltration basins or trenches to an aquifer. Common water sources include dams, rivers, municipal wastewater and storm runoff.

Treatment may need to be sophisticated in order to prevent clogging in the aquifer or at the surface of infiltration basins. In Windhoek, for example, the water is fully treated to domestic supply standards prior to borehole injection, and at Polokwane, the treated wastewater meets the national effluent quality standards prior to discharge into the river bed from where it infiltrates the aquifer.

Treatment may also be simple, such as at Karkams, where an in-stream sand filter is used prior to borehole injection. Wetlands are becoming popular treatment options, in particular for urban runoff.

A wetland in Adelaide, Australia that was constructed to treat urban storm runoff prior to borehole injection



The borehole injection site adjacent to the Adelaide wetland (the borehole is on the left of the picture with the injection pipe rising diagonally to it)

9. ARTIFICIAL RECHARGE SUCCESS FACTORS

The main factors that determine whether artificial recharge is likely to be successful are:

- The quantity, type and reliability of the water source available for recharge;
- The quality of recharge water, aquifer geochemistry, the compatibility of the two waters and clogging issues;
- The hydraulic characteristics of the aquifer and groundwater recovery;
- Economics;
- Management requirements.

9.1 The recharge water source: Quality and reliability

Water sources range from reliable municipal wastewater to ephemeral streams where only opportunistic artificial recharge is possible. Surplus surface water that is available during the rainfall season is a common source.

Water sources for Southern Africa's artificial recharge schemes

Site	Ephemeral rivers	Dams	Municipal waste-water	Urban storm-water runoff
Windhoek		✓		
Atlantis			✓	✓
Polokwane			✓	
Omdel	✓			
Karkams	✓			
Calvinia		✓		

Water for aquifer recharge purposes has to have a consistent quality. High quality, low turbidity water can be used successfully in any kind of recharge system.

9.2 Water quality issues

Various factors influence the quality of the water when artificially recharging an aquifer. However, the initial quality of the recharge water often remains the main factor determining the final water quality.

9.2.1 Recharge water quality

The quality of the recharge water affects the type of artificial recharge scheme that can be employed

Borehole injection schemes require very high quality water. When the water quality needs improvement, for example, to reduce the nutrient or organic compound load, a surface infiltration system may be appropriate. Alternatively, pretreatment options may be necessary to reduce turbidity and improve quality prior to recharge.

Erecting a granular activated carbon filter next to an injection borehole in Windhoek. The water source is fully treated drinking water. This is further treated with granular activated carbon and chlorination to ensure top quality water is transferred to the aquifer.

Karkams' in-stream sand filter ensures that the injected water is of very low turbidity.

The use of treated municipal wastewater as a source for aquifer recharge has been researched extensively. During the treatment process by-products can be produced, and these may present a health threat to water users. It is now known that aquifers have a substantial capacity to change and improve the water stored in them, particularly with respect to disinfection byproducts and pathogens (McCarthy et al. 1981; Gerges, 1996; Pyne, 1998; Toze et al. 2001).

9.2.2 Aquifer geochemistry

The chemistry of the aquifer is a concern where the natural groundwater is not potable. In most cases an understanding of the rock types in the aquifer and the local groundwater chemistry is sufficient to anticipate problems. A more detailed investigation of the rock composition and the chemistry of the groundwater may be needed if reactive minerals are present, or if the rocks or waters contain species of health concern such as fluoride or arsenic.

Mineralisation in Calvinia's groundwater compartment necessitated laboratory analyses to assess the potential for reactions between the recharge water and the rocks after injection.

Rising main encrusted with ferric iron hydroxide (ferrihydrite) precipitates at a groundwater scheme in the Western Cape. Although this picture is not from an artificial recharge site, one would nevertheless not want to unintentionally introduce oxygenated water into an iron-rich aquifer.

9.2.3 Water compatibility

Where the composition of the recharge water is compatible with the groundwater, blending the waters should not cause chemical precipitates to form. If both waters are of good quality, the final water should also be suitable for domestic consumption with little or no treatment after recovery.

Problems may arise if either the recharge water or the groundwater does not meet drinking water standards. This may require a geochemical investigation to assess clogging potential and water treatment needs.

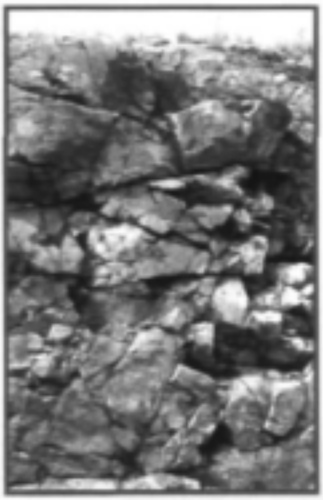
9.2.4 Clogging issues

Clogging of recharge basins, trenches or boreholes causes a drop in the rate at which water is received in the aquifer - the efficiency of the recharge process is reduced. Correctly dealing with clogging plays a decisive role in determining the success or failure of a scheme. Clogging of the system can be due to mechanical, physical, chemical and biological processes, as well as a combination of these. It can take place at the infiltration surface, in the unsaturated zone, or in the aquifer itself. In the case of injection, it could block the fractures leading away from the borehole. A thorough understanding of the processes involved and the consequent reversibility or irreversibility of the situation is needed in order to be able to manage clogging.

Sieving river sand for Karkams' filter in preparation for the next artificial recharge run. Newly sieved sand is used to maintain the filter's efficiency and prevent clogging in the aquifer.

9.3 Aquifer hydraulics and groundwater recovery

9.3.1 Aquifer hydraulics



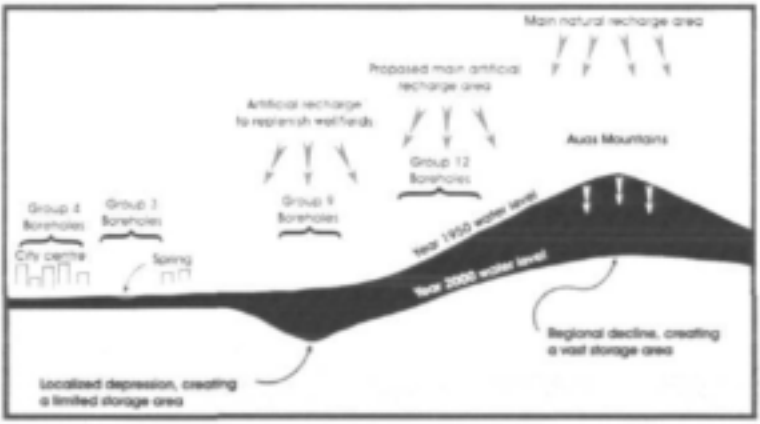
There are two physical characteristics that determine whether an aquifer is suitable for accepting artificially recharged water. They are the aquifer's permeability and storage capacity. Key questions are:

- Is the aquifer sufficiently permeable to allow the recharge water to enter it?
- Does the aquifer have sufficient storage available to accept the water?

Fracturing in the Windhoek quartzites ensure very high permeabilities. Injection rates of up to 60 L/s can be achieved.

Where aquifers have been over-pumped (where abstraction is greater than natural recharge), space will be available for artificial recharge. Artificial recharge, however, should not only be considered as a means of replenishing over-abstracted aquifers, it should also be considered pro-actively as a means of maximising the use of available aquifer storage. This can be achieved by adopting the water banking approach. It can also be achieved by using saline aquifers. Artificial recharge should be considered in poor quality aquifers where the hydraulics is suitable for creating a fresh water "bubble" around the point of recharge. By doing so, a "non-aquifer" can be transformed into a viable storage compartment. Many aquifer storage and recovery (ASR) schemes have been developed in saline aquifers.

The Windhoek scheme has been designed to allow for injection and abstraction in both the wellfields, where localized storage is created by large-scale abstraction, and further a field in the aquifer's main storage area.

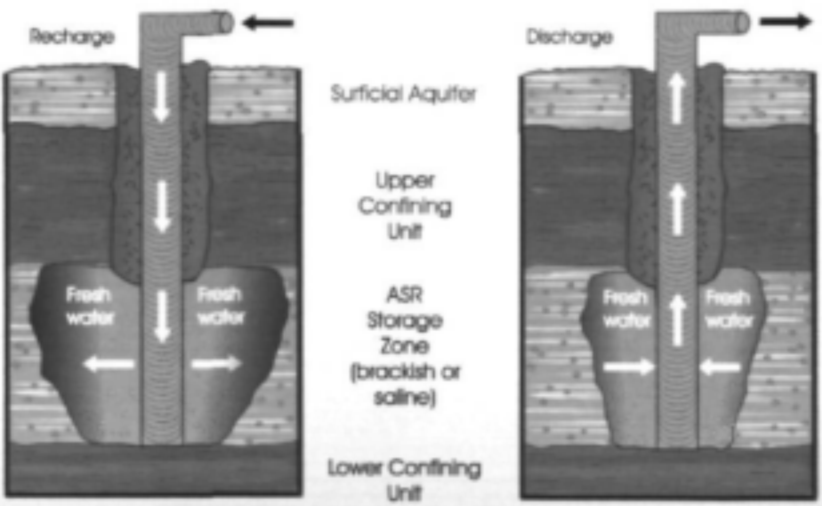


Windhoek's artificial recharge approach

9.3.2 The recovery of artificially recharged water

In most cases, virtually all artificially recharged water is recovered. Unless a scheme is poorly designed, it is unlikely that more water will be lost from sub-surface storage than from surface storage, considering Southern Africa's high evaporation rates.

Where the characteristics and extent of the aquifer are known in sufficient detail, water levels can be managed to prevent losses of artificially recharged water. Part of the management strategy may be to induce flow to the wellfields by large-scale abstraction. Hydraulic gradients can be reversed and water that would otherwise be considered "lost", can be "re-captured".



Creating a "bubble" of fresh water in a saline aquifer

9.4 Economics

Unused aquifer storage capacity can be developed at a significantly lower cost than surface storage facilities, and without the adverse environmental consequences frequently associated with surface storage. Often the overall costs of artificial recharge operations are less than half the capital cost of conventional water supply alternatives, especially those involving development of new reservoirs, treatment facilities or extensive pipelines (National Research Council, 1994).

It is important when undertaking a cost benefit analysis on various water supply options to ensure that all the costs are considered. These should not only include the costs associated with developing and operating the schemes, but also the savings from minimising water losses, particularly evaporation.

Prior to the construction of the Windhoek artificial recharge scheme, two economic feasibility studies were undertaken that compared various water supply options (SWECO International, 2002 & Van der Merwe, 2002). The one focused on modeling the security of supply and economic viability, and the other included conventional cost-benefit analyses (including indicators such as net present value, internal rate of return, payback period and cost benefit ratios). Both recommended that artificial recharge be accepted as the best viable option to augment the city's water supply.

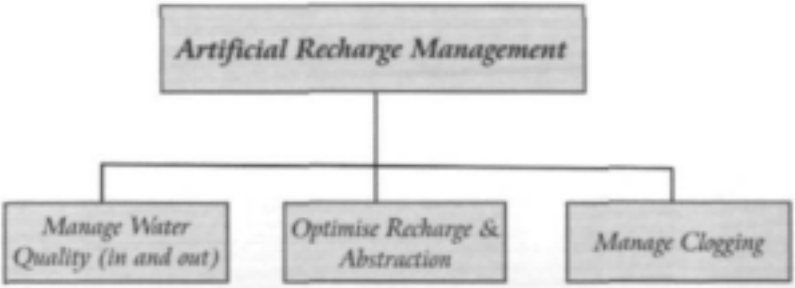
Possibly the greatest potential value of artificial recharge is having a dependable quantity of water held in the water bank. In areas with limited or erratic rainfall, and with climatic change predicted to increase the variability of rainfall, this technology offers a cost-effective option for providing water security.

9.5 Scheme Management

In general, artificial recharge schemes commonly involve surface or wastewater capture, treatment, pumping, distribution, and water level and quality monitoring. In order for these processes to be efficient, careful planning and management is needed.

A full-time person with a good understanding of the aquifer may be needed in order to maximise the efficiency of a large-scale artificial recharge scheme. This is particularly important when clogging prevention and management is a key concern. All schemes will run into problems or lose their efficiency if the responsibility and tasks required to manage the schemes are not clearly defined.

In the case of small scale schemes it may, in certain instances, like at Karkams, be possible to design the scheme for minimal water treatment and maintenance. Nevertheless, some monitoring and maintenance on a regular basis remains essential for ensuring the success of the scheme.



10. SOUTHERN AFRICAN CASE STUDIES

10.1 BOREHOLE INJECTION IN WINDHOEK'S QUARTZITE AQUIFER

The aim of artificially recharging the Windhoek aquifer is to provide the City of Windhoek with water security. The city depends primarily on surface water, but due to unreliable rainfall, reserves in the supply dams regularly run low. Groundwater currently accounts for 10% of the city's water needs, but with large-scale artificial recharge this could be increased significantly - to the extent where the aquifer [or water bank] becomes the city's main water source during droughts. Additional benefits are that it will enable the surface water engineers to operate the dams at higher risk levels and it will provide seasonal storage to meet the high summer demand.

Windhoek with the aquifer's mountainous natural recharge area in the background

10.1.1 Background

Groundwater levels around Windhoek have dropped by tens of metres in the wellfield areas, and are steadily dropping in the natural recharge areas south of the city. Artificial recharge will target both the wellfield and natural recharge areas in order to rapidly replenish the aquifer.

Quartzite mountains rising above the wellfields

10.1.2 Feasibility study

The Windhoek aquifer consists of quartzites and schists. Intense faulting and folding has resulted in a highly fractured and complex aquifer system.

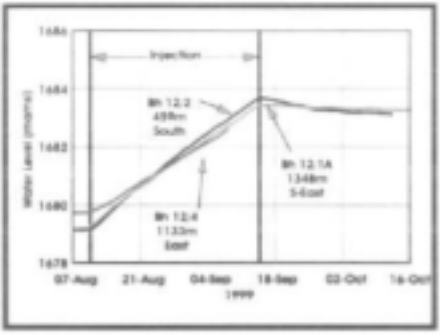
A key challenge was to develop a thorough conceptual groundwater flow model by studying the geology and hydrogeology of the area, and to convert this model into a numerical flow model.

10.1.3 Pilot injection tests

The ability of the aquifer to receive water was established by conducting borehole injection tests. The water source is the city's treated domestic water that comes mostly from their supply dams.

The longest test lasted 195 days and the highest injection rate achieved was 59.4 L/s (214 m^3/hr). These tests showed that the aquifer can be rapidly replenished after large-scale abstraction.

Injection borehole



Borehole injection test at 33 L/s (118 m^3/hr) - water level response in observation boreholes

10.1.4 Implementation

The City of Windhoek adopted a 3-phased approach to implementing large-scale artificial recharge.

Phases	*Injection capacity (million m^3/a)*	*Percentage of city's annual requirements*
Phase 1 *(complete)* *5 existing boreholes to be used for injection and abstraction*	3.7	19
Phase 2 *4 more existing boreholes and 2 new boreholes to be used for injection & abstraction*	8.1	43
Phase 3 *3 more existing boreholes and 7 new boreholes to be used for injection & abstraction*	16.5	87

The long-term goal is to be able to replenish the aquifer as rapidly as possible after periods of high abstraction.

10.2 Small-scale borehole injection in Namaqualand

The village of Karkams, with a mean annual rainfall of 250 mm and a population of 1700, depends solely on groundwater.

Karkams village

Natural groundwater recharge is very low, and as a result of abstraction since the mid 1990's, groundwater levels have dropped tens of metres and the water quality (salinity) has deteriorated significantly. The aim of artificial recharge is to reverse this negative trend by rapidly replenishing the aquifer when river runoff is available.

10.2.1 The hydrogeological setting

The Karkams aquifer consists of granites and gneisses cut by major faults on which high yielding boreholes are sited. The groundwater quality is characterized by relatively high salinities (~250 mS/m), and high fluoride (~ 3 mg/L). The water quality changes from relatively fresh water near the surface to older, more stagnant water at depth.

Pump house for the injection and abstraction borehole

10.2.2 The artificial recharge scheme

The scheme consists of a sand filter that is built in the bed of an ephemeral river. Most of the water, when available, flows over and past the filter, but some infiltrates the sand filter and is gravitated to the injection boreholes. The only maintenance required during operation is weekly removal of the fine sediment that settles on the filter since it slows down infiltration.

Layout of the artificial recharge scheme

Sieving river sand for the sand filter

Sand filter with the pump house in the background

10.2.3 Borehole injection tests

Three controlled injection runs from 1999 to 2001 had the effect of reversing the declining water level trends. During the longest test, which lasted for 138 days, 6 567 m^3 was injected. This is more than twice the annual sustainable yield of the borehole (2 400 m^3/a).

The water quality improved significantly after injecting the clear, filtered river water. With three consecutive years of artificial recharge, the electrical conductivity values dropped from over 250 mS/m prior to injection to less than 100 mS/m after injection.

10.2.4 Conclusions at Karkams

This case study demonstrates the value of opportunistic artificial recharge, and that a very low yielding borehole and a low yielding aquifer can be recharged at relatively high rates. An additional benefit of introducing fresh water to the aquifer is that it significantly lowers the salinity of the groundwater.

During years with rainfall, this scheme provides good quality water to the residents of Karkams. This is water that would otherwise be lost to evaporation. The Karkams case study shows that this technology is not only applicable to large-scale schemes, but that it can be used effectively in small-scale operations. It also shows that the principle of conjunctive use is valuable in augmenting Southern Africa's rather limited natural recharge.

10.3 Atlantis: 20 years of artificial recharge using infiltration basins

(adapted from G Tredoux, E C Murray & L C Cavé, 2002)

The town of Atlantis, located 50 km north of Cape Town, has a population in excess of 100 000. It was initially fully dependent on groundwater, however, the reserves were insufficient, and artificial recharge was introduced to augment local groundwater supplies. The recharge system, using urban runoff and high quality treated domestic wastewater, has been in operation for more than 20 years.

One of the infiltration basins

10.3.1 Hydrogeology

This thin, coastal aquifer consists of unconsolidated dune sands with an average thickness of 25 m. Natural recharge is estimated to be in the order of 15 - 30% of the annual rainfall (450 mm).

10.3.2 Artificial Recharge Water Source and Scheme Design

The town was planned with fully separated residential and industrial areas. This fact contributed to the success of the artificial recharge operation, as inferior quality storm runoff and wastewater from the industrial area is diverted and not used for artificial recharge purposes.

Atlantis infiltration basins and wellfields

Low salinity storm runoff and high quality treated domestic wastewater are channelled into two large spreading basins for artificial recharge up gradient of the main wellfield.

Treated industrial wastewater, industrial area storm runoff and the relatively high salinity baseflow is diverted to the coastal recharge basins in order to create a hydraulic mound for preventing seawater from intruding into the wellfield.

A coastal infiltration basin

10.3.3 The effectiveness of artificial recharge

The infiltration rates achieved in the basins range from 0.01 to 0.16 m/day depending largely on the thickness of the unsaturated zone.

Storm runoff and wastewater infiltration augments the natural recharge of the groundwater in the main wellfield area (the Witzand unit), by 1.5×10^6 to 2.5×10^6 m^3/a.

10.3.4 Main operational challenges

Managing water quality and, in particular, salinity has been one of the greatest challenges for the Atlantis Water Scheme. The recent importation of limited quantities of surface water from outside the catchment is an important additional source of low salinity fresh water entering the system.

A decline in the yield of the boreholes in the Atlantis aquifer led to the discovery of iron-related clogging problems. The cause of the biofouling problem was suspected to be over pumping of the boreholes, which allowed ingress of oxygen into the aquifer.

10.3.5 Conclusions

Artificial groundwater recharge ensured the sustainability of the Atlantis water supply for over two decades and will continue to play a key role. A major component of the scheme has been the separation of the source water into different fractions, as this has allowed recharge of the highest quality water in the areas of greatest importance.

The Atlantis groundwater scheme provides a cost-effective water supply option when coupled with careful management of the water sources and the aquifer.

10.4 Recycling Polokwane's treated wastewater

Polokwane's business area

Polokwane, with a population in excess of 400 000 and water requirements of about 12 million m^3/a, is largely dependent on surface water. However, the town also has an elaborate groundwater abstraction infrastructure that can supply domestic water in times of surface water shortages and during periods of peak demand. During the 1992 to 1994 drought, groundwater accounted for a large proportion of the city's needs (3.7 million m^3/a).

The reliability of this source is largely due to the infiltration of treated municipal wastewater into Polokwane's alluvial and gneissic aquifers.

10.4.1 Hydrogeology

Treated wastewater is discharged into the ephemeral Sand River, which flows over a ~20 m thick by 300 m wide layer of alluvium. Underlying the alluvium are granite-gneiss rocks that are weathered and fractured to depths of 60 m. The production boreholes penetrate this deeper, hard-rock aquifer.

Abstraction borehole near the riverbed

10.4.2 The wastewater infiltration scheme

Water handled at Polokwane's Waste Water Treatment Works (WWTW) goes through both primary and secondary treatment prior to retention for 2 to 3 weeks in a series of maturation ponds. The quality of the wastewater discharge is maintained within the national effluent quality standards.

Polokwane's Waste Water Treatment Works

Each year about 6 million m^3 of water is released from the WWTW. Of this, about 2 million m^3 is lost through evapo-transpiration, leaving about 4 million m^3 for recharging the gneissic aquifer.

One of Polokwane's three maturation ponds

Treated wastewater discharging into the Sand River

10.4.3 Water quality issues

The treated wastewater is further treated by sand filtration before it enters the hard-rock aquifer below the alluvium. As with all artificial recharge schemes of this nature, the filtration process improves the physical, chemical and microbiological quality of the water. When this groundwater is reused, after blending with the natural groundwater in the aquifer, it is again treated and blended with surface water.

10.4.4 Conclusions at Polokwane

About 4 million m^3 of the 6 million m^3 of treated wastewater discharged into the normally dry Sand River can infiltrate the sandy and gneissic aquifer, and be available for reuse. This constitutes approximately one third of the city's current water requirements. If this water was not recycled through artificial recharge and subsequent abstraction, it would either be lost to evapotranspiration or it would be pumped from the river or aquifer by other users downstream of the discharge point. In order for the Polokwane municipality to recycle as much of this water as possible, it needs to continuously abstract from the gneissic aquifer. In this way space is created in the aquifer, and the recycling process is made possible.

As with all artificial recharge schemes that rely on treated wastewater, regular monitoring and management of the wastewater and the abstracted groundwater is required to ensure high quality water is supplied to the consumers.

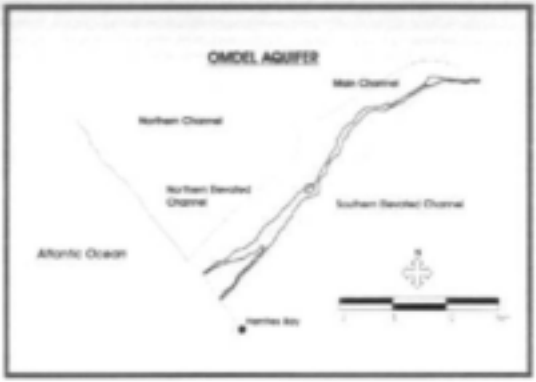
10.5 Infiltration basins in the Namib Desert

(by Surene Zeelie)

The coastal towns of Henties Bay, Swakopmund and Walvis Bay, with a mean annual rainfall of less than 50 mm/a, depends solely on groundwater. These towns are supported by two borehole schemes associated with groundwater in paleochannel systems, of which the OMDEL (Omaruru Delta) Aquifer is used for artificial recharge and abstraction.

Natural groundwater recharge is very low and only occurs when floods occur in the ephemeral Omaruru River. As a result of over-abstraction since the mid 1970's, groundwater levels have dropped tens of metres. The aim of artificial recharge is to reverse this negative trend by rapidly replenishing the aquifer when river runoff is available.

Swakopmund



The Omdel Aquifer

10.5.1 The hydrogeological setting

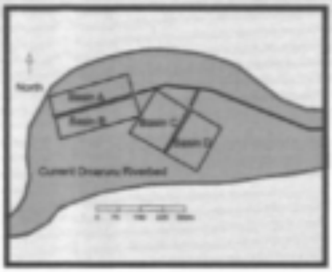
The OMDEL aquifer system consists of an alluvium wedge incised into granite. Of the four paleochannels present, only the Main Channel contains potable water.

Recharge is severely hampered by silty clay layers deposited on the surface of the riverbed, and as a consequence only ~1 million m^3/a recharges the aquifer after an average 14 million m^3/a flood event.

10.5.2 The artificial recharge scheme

The artificial recharge scheme consists of four infiltration basins. These are operated in a routine of infiltrating, drying, scraping and refilling. Infiltration starts at a rate of 1.2 m/d and can be maintained for 2 weeks.

Thereupon rapid clogging (silt) decreases the infiltration rate to 0.5 m/d and the top 5-10 cm of silt is removed with a grader after drying. The entire infiltration cycle normally continues for approximately 3 weeks.



Layout of the infiltration basins

The two western infiltration basins

10.5.3 The effectiveness of artificial recharge

There have been two artificial recharge events since the construction of the scheme. One was in 1997/8 and the other in 2000. In both cases 18 million m^3 was retained in the OMDEL dam for the purpose of recharging the aquifer. It is estimated that 52 - 53% of this volume was successfully infiltrated to the aquifer after each event. This is water that would otherwise have been lost to evaporation. As it is, most of the retained water that did not infiltrate the sub-surface was lost to evaporation.

10.5.4 Conclusions at OMDEL

This case study shows that even in arid areas artificial recharge by means of infiltration basins can significantly increase the stored water reserves. Surface runoff that would normally be lost to evaporation can be safely stored in the underground.

The operation of the scheme is cheap and easy. It is, however, essential to have a dedicated operation and maintenance team to maximise infiltration and the effectiveness of the scheme.

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