Interreg CENTRAL EUROPE

DEEPWATER-CE

European Union European Regional Development Fund

1st Training DEEPWATER-CE Interreg Project

Good Practice and Benchmark Analysis of MAR

A.T1.3 Capacity building to stakeholders in order to ensure integrated environmental approach on MAR

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TUM
Chair of Hydrogeology
TUM Department of Civil, Geo and Environmental Engineering
Technical University of Munich

Managed Aquifer Recharge Webinar 23.09.2020

Held in the framework of the DEEPWATER-CE Interreg Project about developing an integrated implementation framework for Managed Aquifer Recharge solutions to facilitate the protection of Central European water resources endangered by climate change and user conflict

Time (UTC+2)	Agenda
13:30-14:30	Good Practice and Benchmark Analysis of MAR
14:30-15:00	Virtual Coffee Break
15:00-16:00	Transnational Decision Support Toolbox for designating potential MAR locations in Central Europe

Location:
ZOOM Conference Room
https://tum-conf.zoom.us/j/97349866167
Meeting ID:
973 4986 6167
Password: 346397

Contact:
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Dr. Arno Rein (arno.rein@tum.de)

Communication

- Mute your microphone unless you are speaking
- Please switch-off your camera unless you are speaking
- When you want to ask a question during the presentation use the 'raise your hand' function or post in the chat
- The webinar will be recorded and uploaded on social media

DEEPWATER-CE Project

Cooperating on natural and cultural resources for sustainable growth in Central Europe (CE)

Developing an integrated implementation framework for Managed Aquifer Recharge solutions to facilitate the protection of Central European water resources endangered by climate change and user conflicts

DEEPWATER-CE Project

1. Development of **transnational knowledge base** on the applicability of MAR in CE (Good Practice and Benchmark)
2. Development of transnational assessment methodology/ **toolbox** for decision-making on MAR locations in CE
3. Feasibility assessment of MAR schemes in CE with **pilot sites**
4. Development of policy recommendations and **national action plan**

Research focus TUM

- Characterization of water availability & flow in the unsaturated and saturated zone
- Investigation of aquifer vulnerability; pollutant fate and water purification potentials
- Stable water isotopes combined with modeling
- Numerical modeling, stochastic and Monte Carlo based techniques

MAR principles - DEFINITION

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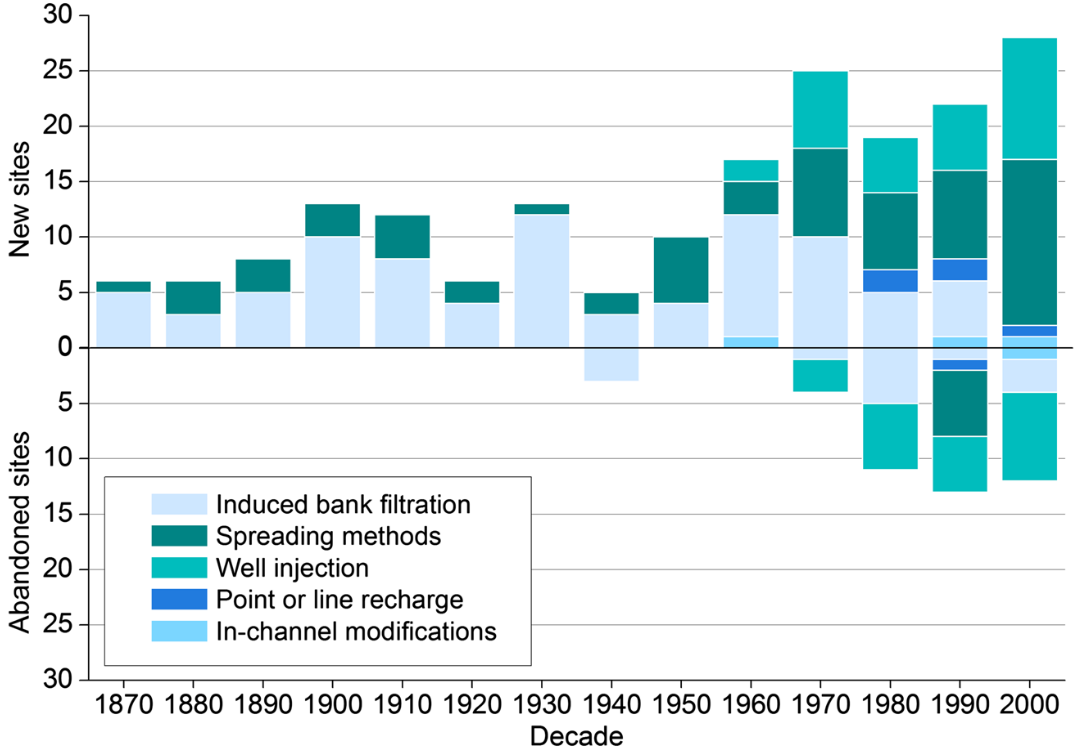
Managed Aquifer Recharge (MAR)

- is a term conceived by the British hydrogeologist Ian Gale, who was the founding co-chair of the International Association of Hydrogeologists (IAH) Commission on Managing Aquifer Recharge (from 2002 to 2011)
- it refers to methods which are increasingly used to maintain, enhance and secure groundwater systems under stress
- simplified, **MAR is an intentional process by which excess surface water is directed into the ground** — either by spreading on the surface, by using recharge wells, or by altering natural conditions to increase infiltration in order to replenish an aquifer.

MAR principles - BRIEF HISTORY

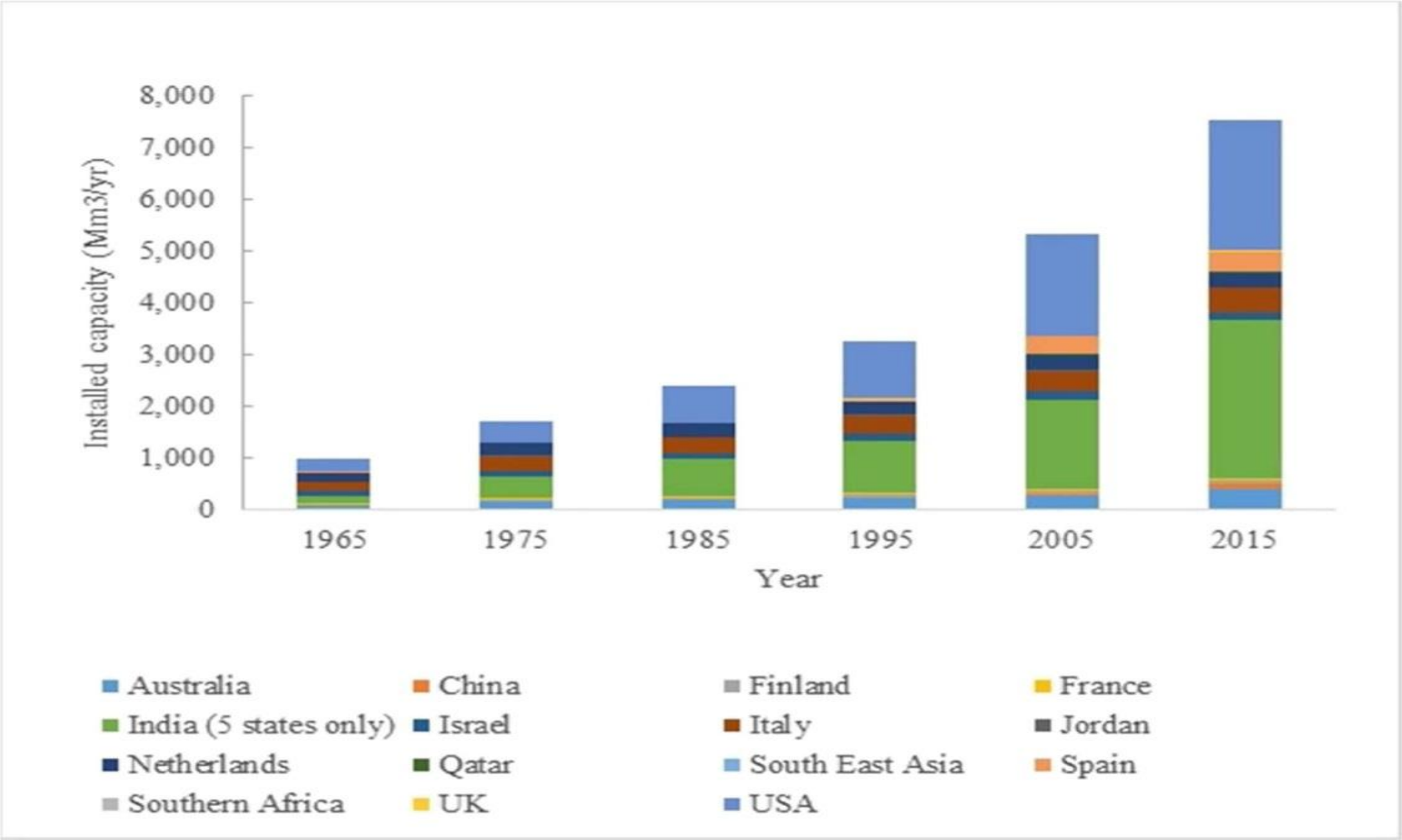
- The first reported MAR site in Europe was **in 1810 in Glasgow (UK) -** Glasgow Waterworks Company constructed a perforated collector pipe to abstract bank filtrated water
- Predominantly two techniques firstly known as MAR were used :
  - **induced bank filtration**
  - **surface-spreading methods**
- The idea was spread to the Netherlands, Belgium, Sweden, France, Austria and Germany
- Research and development of well injection methods began in the 1960s.

Outline of the historical development of MAR in Europe showing the number of MAR sites



(Sprenger et al. 2017)

MANAGED AQUIFER RECHARGE IN THE WORLD



(Dillon et al., 2019)

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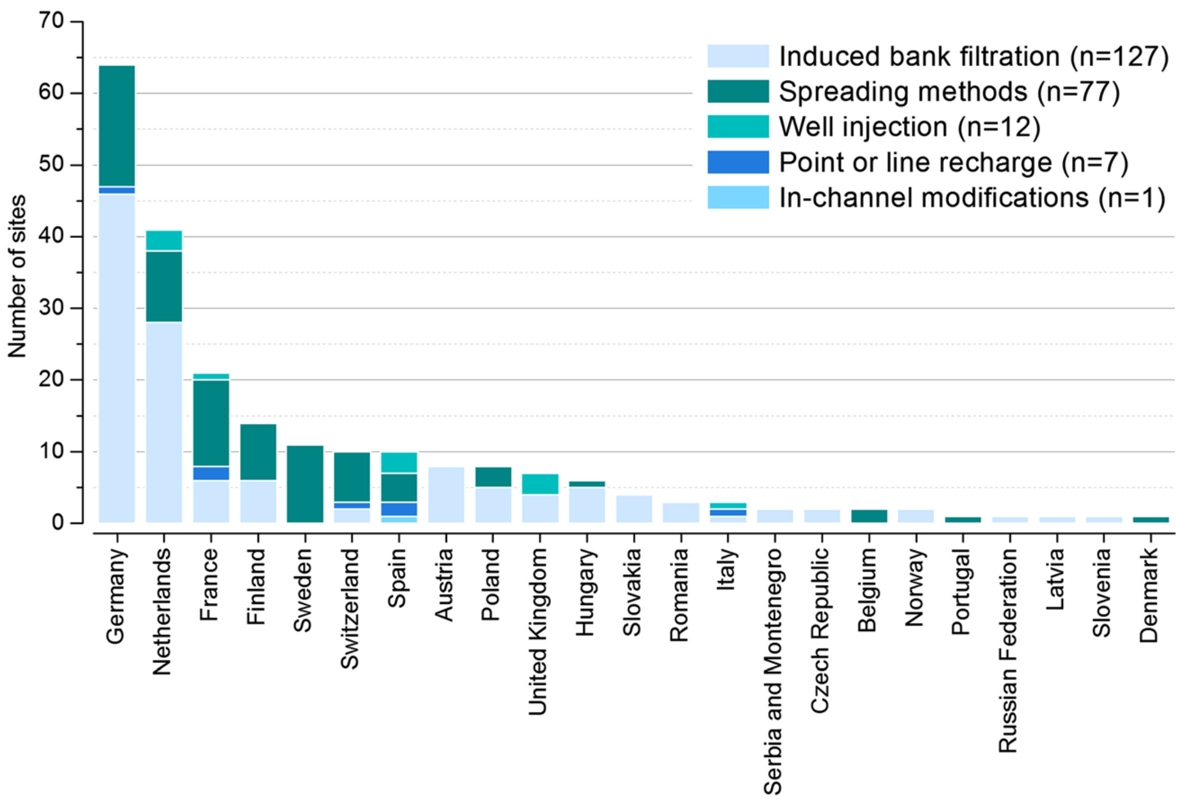
MANAGED AQUIFER RECHARGE IN EUROPE



Active MAR sites and types for Europe in 2013 (Sprenger et al. 2017)

MAR principles - OBJECTIVES AND CRITERIA

MAR is applicable in sustaining and improving groundwater quality, quantity and also in environmental management.

Water quality:

- to improve water quality in degraded aquifers (e.g. nutrient reduction from agricultural pollution, prevention of seawater intrusions) and reducing the concentration of geogenic pollutants (e.g. Fluoride or Arsenic)
- to reduce effort for water treatment (e.g. natural purification processes such as riverbank filtration).

Water quantity:

- to store water in aquifers for future use (e.g. water supply);
- to increase groundwater levels in over-exploited aquifers.

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Environmental management:

- to prevent storm runoff and soil erosion
- to preserve environmental flows in rivers and streams
- to mitigate floods and flood damage
- to provide hydraulic control of contaminant plumes
- to increase groundwater levels to maintain or improve the status of groundwater dependent terrestrial ecosystems

MAR principles - TYPES (IGRAC, 2007)

	Main MAR Methods	Specific MAR Methods
Techniques referring primarily to infiltrating water	Spreading methods	Infiltration ponds
		Flooding
		Ditches and furrows
		Excess irrigation
	Induced bank filtration	River/lake bank Filtration
		Dune filtration
	Well, shaft and borehole recharge	Aquifer Storage and Recovery (ASR)
		Aquifer Storage, Transfer and Recovery (ASTR)
		Shallow well/shaft/pit Infiltration

MAR types - Infiltration Pond

Advantages:

- large quantities of water - low cost
- Water purification potential

MAR types - Ditches

<u>Advantages:</u>

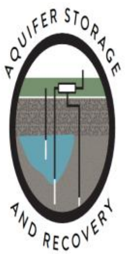
- low land use, can be underground
- Water purification potential

MAR type - Induced River and Lake Bank Filtration

Advantages:

- large quantities of water
- Water purification potential

MAR type - Aquifer Storage and Recovery



Advantages:

- infiltration of large quantities of water
- Low land use

MAR principles - TYPES (IGRAC, 2007)

	Main MAR Methods	Specific MAR Methods
Techniques referring primarily to intercepting water	In-channel modifications	Recharge dams
		Underground dams
		Sand dams
		Channel spreading
	Runoff harvesting	Rooftop rainwater harvesting
		Barriers and bounds
		Trenches

Watch MAR principles:
https://www.youtube.com/watch?v=NUM9OAKjcyA

Recharge Dam

Advantages:

- Structures are installed in streambeds □ lower land use

Underground Dam

Advantages:

- Low cost structures
- low maintenance
- low land use

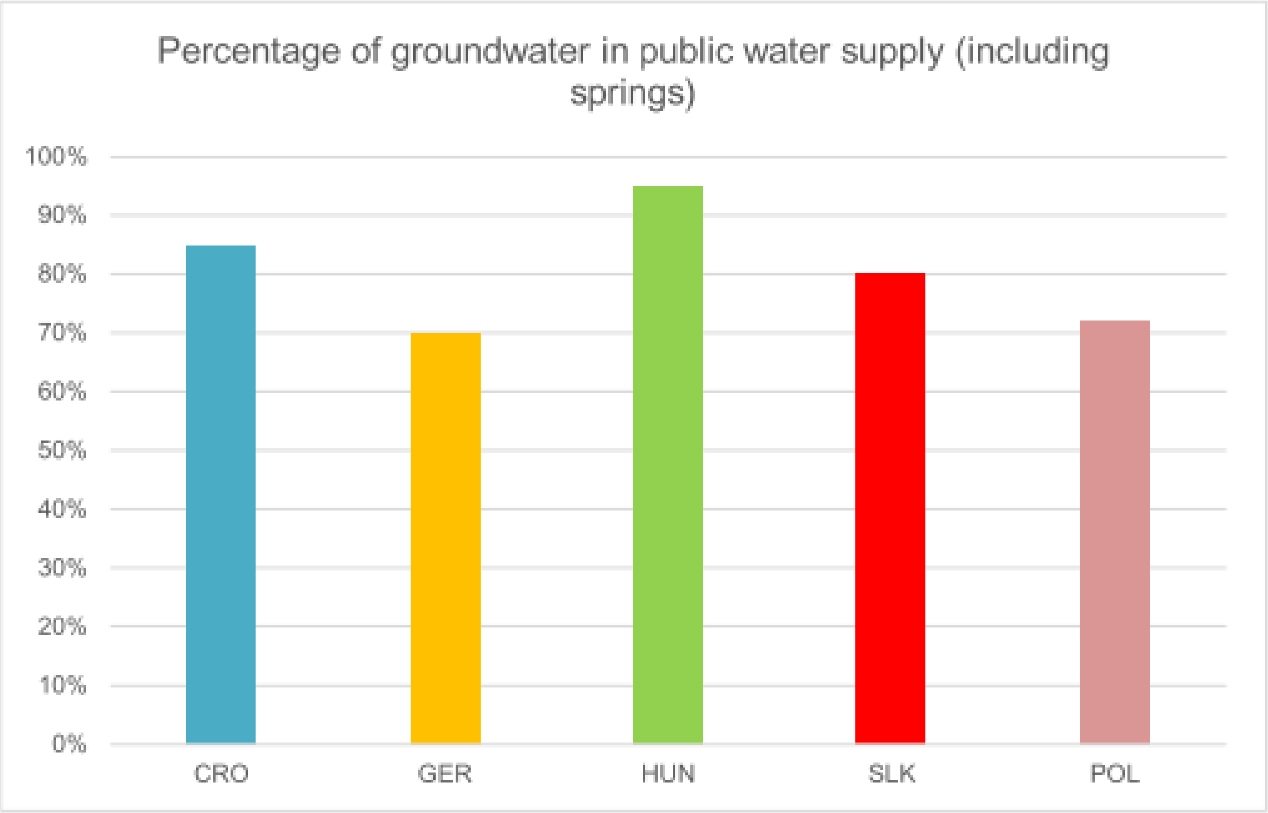
Possible water sources:

- ✓ surface water
- ✓ rain water
- ✓ storm water
- ✓ reclaimed water
- ✓ groundwater

DEEPWATER-CE Project: Pilot Feasibility Study

Porous aquifer	Porous aquifer	Porous aquifer	Karst aquifer
Irrigation	Agricultural impact	Influence of Industrial Site	Tourism seawater intrusion

DEEPWATER-CE Project: Partner Countries



FACTORS INFLUENCING FEASIBILITY AND PERFORMANCE OF MANAGED AQUIFER RECHARGE

1. Hydrogeological settings
2. Climate and hydrology (MAR solutions are crucial to tackle climate change impacts, e.g. declining of groundwater tables, deteriorating of water quality, etc.)
3. Biogeochemical processes
4. Monitoring
5. Costs and risks

FACTORS INFLUENCING FEASIBILITY AND PERFORMANCE OF MANAGED AQUIFER RECHARGE

WP 2: Toolbox

1. Hydrogeological settings
2. Climate and hydrology (MAR solutions are crucial to tackle climate change impacts, e.g. declining of groundwater tables, deteriorating of water quality, etc.)
3. Biogeochemical processes
4. Monitoring
5. Risks and Cost

WP 3: Feasibility Study Guidelines

3. Biochemical processes

- In the infiltration techniques - geochemical and microbiological processes in the unsaturated zone enable purification of the recharged water.

- The main criteria affecting the geochemical and microbiological processes:
- pH,
- redox potential,
- organic matter content
- mineralogy.

- mobilization of ions, clogging…

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Ways of monitoring:

- usage of **multi-parameter probe** systems with continual detection of several chemical-physical variables.
- get better tools **to predict clogging** and apply inhibition
- isotopes usage to study origin and age of groundwater, **mixing processes, travel times of recharged water and biogeochemical processes** (e.g. denitrification, sulfate reduction, origin of organic carbon and dissolution of minerals)
- **modeling of flow and water quality changes in MAR operations** – to improve planning and design of MAR systems

5. Risks and Costs (1)

Strategic risks

- Need for water
- Management and technical capability
- Business case for scheme
- Availability, reliability, quantity and acceptability of source water
- Proximity of supply & demand
- Regulatory requirements

Pre-treatment

- Reliability of technology (risk of failure)
- Resilience to changes in influent quality and quantity
- Appropriate to mitigate clogging and other reactions that may occur during storage?
- Regulatory risk – changing standards
- Change in enduse

Recharge

- Injection
  - High injection pressures
  - Impact on groundwater dependant ecosystems
  - Clogging resulting in higher injection pressures
- Infiltration
  - Clogging of the soil

Aquifer storage

- Mixing with native groundwater
- Adsorption
- Degradation via microbial activity
- Redox reactions
- Advection/ flow rate
- Loss of recharged water
- Clogging of aquifer
- Dissolution/ precipitation
- DBPs

Recovery

- Clogging
- Reduction in recovery effeciency
- Impact on groundwater dependant ecosystems
- Loss of water due to other abstractions

Post Treatment

- Impact of reactions and mixing in aquifer on treatment
- Does abstracted water meet end use requirement
- Ability to adapt to varying quality water
- Regulatory risk – changing standards for end use

(Nandha et al. 2015)

Cost of MAR:

- Capital, operation / maintenance and finance costs
- Main factors influencing the costs:
    - MAR type
    - necessary pre-treatment of source water
    - labour costs

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Average MAR scheme costs, by MAR type (Ross and Hasnain, 2018)

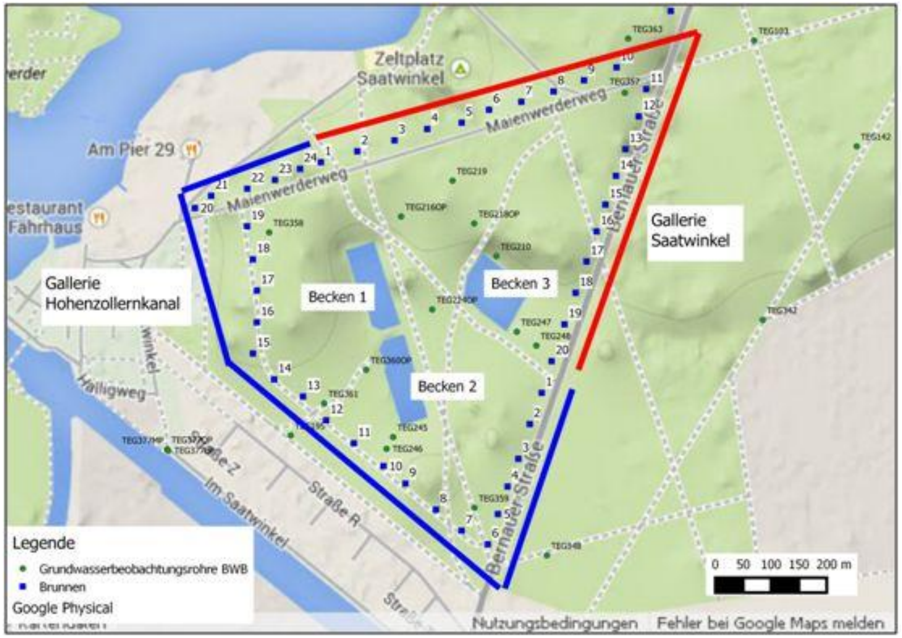
MAR operation Type/ Water Source	Capital cost / m^3 recharged	O&M* cost / m^3 recharged	Levelised cost (US$ / m^3 recharged)
Recharge wells / recycled water (4 schemes)	$ 8,07	$ 0,53	$ 1,16
Infiltration basins / recycled water (3 Schemes)	$11,41	$ 0,84	$ 1,89
Recharge wells/ natural water (5 schemes)	$ 3,29	$ 0,19	$ 0,45
Infiltration basins / natural water (8 Schemes)	$ 0,77	$ 0,13	$ 0,19

Implementation process can include the following steps:

- selection of recharge methods and areas
- legal and institutional framework with proper assessment
- risk characterization and preventive measures
- monitoring and verification of water quality and environmental performance
- operational issues and their management (e.g. clogging, contamination)
- Economic aspects

MAR type - *Infiltration lakes and ponds*

Berlin - Lake Tegel (Germany)



https://demeau-fp7.eu/toolbox/demeau-case-studies-operation/mar-profiling/berlin-tegel-germany

Water source: Lake Tegel

3 infiltration ponds

Pre-treatment: micro strainer (pore size diameter of 28 µm) prevent clogging by algae in Summer

Aquifer type: porous

- 40 production wells

Residence time: >50 days

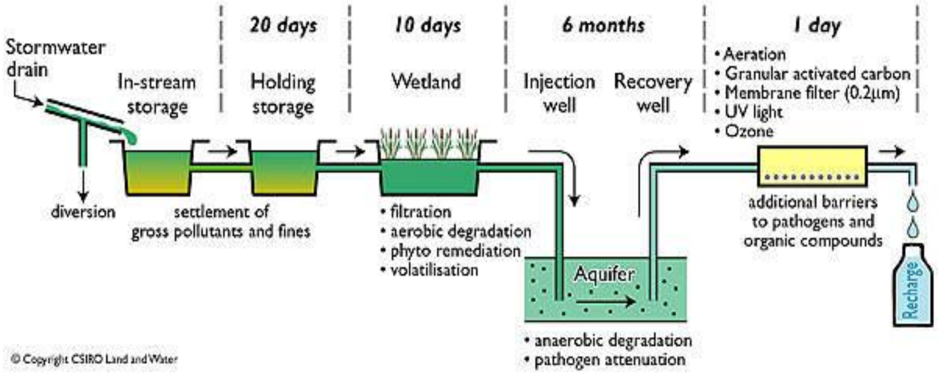
Post-treatment: aeration and slow sand filtration

Water recovery: 21 m^3/y

End-use: Drinking water supply

MAR type - *Stormwater injection system*

Salisbury (South Australia)



https://www.water-technology.net/projects/aquiferstoragetransp/

Aquifer type: approx. 60 m thick low to moderate porous limestone

Wells (165-182 m)

- 4 injection wells
- 2 production wells

Quality monitoring of injected (recharge) water

Subsurface storage time:

12-15 months

Post-treatment: Fe removal

End-use: drinking water supply

MAR type - Infiltration ponds, dams

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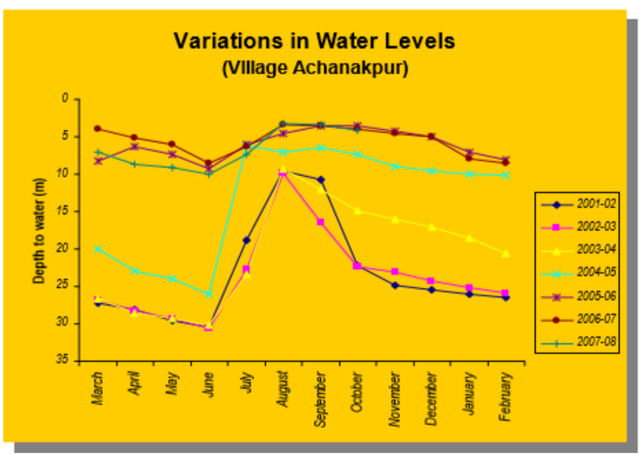

(Central Ground Water Board, Ministry of Water Resources, New Delhi, 2011)

Gujra Sub-Watershed (India)

Rainwater Harvesting system

Year of completion: 2003-2005

Average annual rainfall: 1200 mm

- 23 stop dams (1-1.5 m)
- 28 desilting ponds
- 12 percolation tanks
- 13 silt traps (0.5-0.7m)
- 8 monitoring wells

End use: agriculture, irrigation

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Thank you for your kind attention


Virtual

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