Assessing the feasibility of Managed Aquifer Recharge at Palla Road, Botswana

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Why large-scale MAR in Botswana?

• Arid – semiarid climate

• Expected sharp increase in water demand (+77% for Gaborone 2020-2040) will create risks for the water security

• During years with excessive precipitation the MAR system would allow long-term storage of water that otherwise would have been lost as outflow from dams.

• The MAR-scheme would be connected to the North-South Carrier bulk water supply system and thus contribute to the water security of the capital Gaborone.
Feasibility study for MAR at Palla Road Wellfield

Project main objective:

Evaluate the feasibility of large-scale MAR in the Ntane sandstone aquifer at Palla Road wellfield (approx. 150 km N of Gaborone) and its effects on the water security of Gaborone and connected demand centres along the NSC-system.

Collaboration

- Botswana Department of Water and Sanitation
- Sweco International AB
- Chalmers University of Technology
- Sub-consultants: WCS (Botswana), GEOSS (RSA)
- Botswana Water Utilities Corporation
Inception phase

Assessment of existing infrastructure

Hydrochemical assessment

Works – drilling, pump tests, injection tests

Development of MAR scenarios

Modelling - Geochemical - Groundwater - Water Supply Safety NSC

Multi Criteria Analysis of scenarios

Preliminary infrastructure design and costing

MAR Feasibility Report

Method approach
Evaluate MAR from a system as well as hydrogeological perspective

- Does MAR work at Palla Road?
  - Can we recharge the aquifer?
  - Can we abstract the recharged water or is there a risk of losing it?
  - What happens with the water quality? Recharge vs native groundwater interactions. Clogging?

- Does MAR at Palla Road contribute to increase the water security of NSC-system and Gaborone?
  - When is there excess water in the system to recharge the MAR system?
  - What capacity is needed to provide a tangible increase to water security

Tasks related to evaluating MAR from a system as well as local hydrogeological perspective include:

- Injection tests
- Geochemical assessment and modelling
- Numerical groundwater modelling of MAR in SPRING (finite elements)
- Develop and apply a comprehensive and dynamic water balance model (water supply security model, WSSM)
- Iterative simulations WSSM and SPRING models
- Evaluate the sustainability of MAR scenarios using Multi-Criteria Analysis (MCA), incl. economic, environmental, social, technical and reliability (risk) performance
Injection tests

- Can the Ntane sandstone aquifer be recharged through borehole injection?
- Fractured sandstone aquifer, depth 100-150 m, SWL 60-70 m
- Short term injection tests in 3 sites (step injection tests + CRIT for 8 days), Q up to 65 m³/h
- Recharge water sourced from other boreholes in the area (distance approx 1500 m)
Hydrochemical study including geochemical modelling

- Characterisation of project area hydrochemistry
- Geochemical modelling in PHREEQC of mixing native groundwater with recharge water as well as rock-recharge water interactions to assess potential for mineral precipitation and clogging
Numerical Modelling of different scenarios

ASR (Aquifer Storage and Recovery)

ASTR (Aquifer Storage, Transfer and Recovery)
Water Supply Security Model (WSSM)

- Probabilistic (stochastic) and dynamic (time-dependent)
- Incl. all major components of the supply system
- Periods (time step 1 month)
  - Simulating water demand and availability 2020-2040
- North-South Carrier (NSC) System
  - A bulk water supply system
  - 360 km pipeline
  - 6 surface water dams
  - 9 wellfields
  - 7 water works
  - 18 demand centres
WSSM results

Volumetric reliability: Gaborone and connected demand centres

- Mean - MAR 20 000 m³/d (30%)
- P10 - MAR 20 000 m³/d (30%)
- Mean - MAR 40 000 m³/d (30%)
- P10 - MAR 40 000 m³/d (30%)
Multi Criteria Analysis (MCA)

A tool for multi-criteria analysis (MCA) provides a structured comparison of different MAR scenarios relative to non-MAR evaluating technical, environmental, social and economic performance:

- ASR 40,000 m³/d
- ASR 20,000 m³/d
- ASTR 20,000 m³/d
Preliminary design & costing + small EIA

Preliminary design include:
• Pre-treatment of recharge water prior to injection (sand filter, GAC, chlorination)
• Water distribution to recharge boreholes
• Infrastructure for borehole injection
• Pump station to convey abstracted water to NSC
Main conclusions

- The Ntane Sandstone aquifer in the Palla Road wellfield is suitable for MAR by means of borehole injection considering e.g. hydrochemistry and low risk of losing water.

- A MAR-scheme can reduce surface water losses from dam due to evaporation and spill over with 26.4 Mm$^3$ between 2020-2040.

- Volumetric reliability in Gaborone and connected demand centres increase with 6% during the period 2020-2040 for MAR 40,000 m$^3$/d scenario.

- Number of months with water shortage are reduced from 77 in the reference scenario to 38 in the 40,000 m$^3$/d scenario.

- MAR provides a more long-term sustainable use of the Palla Road aquifer, due to less depletion of storage over time.

- The increased demand for water reduces the potential of MAR being effective, since time for injection is limited (i.e. all water in NSC system is needed for water supply).
Main recommendations

• A MAR-scheme with a capacity of 40,000 m3/d should be prioritised in coming plans on implementing MAR in the Palla Road aquifer.

• A long-term (24 months) Pilot Test with 2500 m3/d recharge and abstraction capacity should be implemented to confirm the findings in this study. This Test can be seen as the first step in a step-wise development of a MAR-scheme.
Thank you

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