MAR suitability mapping combined with field examination and numerical simulation in the Danube-Tisza Interfluve

Zsóka Szabó, Márk Szijártó, Marco Masetti, Daniele Pedretti, Ferenc Visnovitz, Judit Mádl-Szőnyi

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1. Introduction and aims

- **Water level drawdown** in the area due to climate change and additional anthropogenic effects

- Numerous replenishment plans were worked out in the past decades but using **Managed Aquifer Recharge** hasn’t been considered yet

- The aim of this research is to find **suitable areas** for MAR and to assess water recharge possibilities in a local study area

![Water level changes between 1956-60 and 2002 (VITUKI, 2002)](image)

![Reasons of groundwater level reduction (based on Pálfai, 2010 and Nagy et al., 2016)](image)
2. Study area

- Located in Hungary, in the Danube-Tisza Interfluve (DTI)
- DTI is a ridge region, up to 130 m a.s.l. between Danube and Tisza Rivers
- The river valleys are situated at 85-90 m above sea level
- Alluvial sediments of Danube and aeolian sands

Location of Hungary (a), the Danube-Tisza Interfluve – DTI (b), the regional study area – RSA (c, red rectangle) and the local study area – LSA (c, blue rectangle)

(Fig. 1c map modified from Kohán & Szalai, 2014)
The area’s groundwater flow systems are characterized by a gravity driven meteoric water and an over-pressured saline water.

The shallow flow systems of the elevated ridge region are under the effect of gravity driven meteoric flow regime.
3. Research background

- Water management problems in the broader area have been known for decades.
- One of the most recent plans was to move water from the Danube Valley Channel to the center of the ridge, through existing channels and lakes (Nagy et al., 2016).
- Too expensive and not effective enough as the water can easily infiltrate from the channels and it would not reach the higher regions in sufficient amount.
- One of the aim of this research is to find suitable areas for MAR utilisation.
4. Methods

- **Suitability mapping** (Silva Cisneros, 2019) for the Western Water Supply Area (Regional Study Area – RSA)
- **Field measurements** (Local Study Area – LSA)
  - ERT and RMT geophysical measurements
  - Drilling by hand and soil sampling
  - Water level and water chemical measurements
- **Laboratory measurements** (LSA)
  - Water chemical measurements
  - Sieving and elutriation of soil samples
- **Numerical modeling** (LSA, cross section)
5. Suitability mapping

- Based on near surface geology and water table depth (slope is not an important factor in this area)
- A local study area was chosen based on the final suitability map

Silva Cisneros, 2019 and Mádl-Szőnyi et al., 2019
6. Field measurements

- Geophysical measurements (RMT, ERT)
- Drilling and soil sampling
- Water level and water chemical measurements
Based on ERT and RMT measurements 3 different layers could be distinguished:

1) **Upper aquifer**: a relatively dry upper layer which is approximately coincident with the vadose zone (based on the geophysical measurements it can not be distinguished unequivocally).

2) **Aquitard**: a middle layer, with relatively low resistivity, higher clay content.

3) **Lower aquifer**: a third layer, which is probably more compact and has a lower hydraulic conductivity, than the upper layer, but still a relatively good aquifer.

Inverted result of the ERT measurement (ERT 2); RMT measurements (11-7), and the locations of soil samples.
7. Results of field measurements

Piper-diagram

Tomographic fluid potential map, horizontal flow direction

Stiff-diagrams

from the Lower Aquifer
Possible Managed Aquifer Recharge methods

Infiltration pond

Shallow well

https://inowas.com/managed-aquifer-recharge/
8. Numerical modeling

- Possible modeling scenarios regarding geological build-up
  1. Homogeneous, 1-layer model for only the Upper Aquifer
  2. 3-layer model (continuous aquitard in between)
  3. 3-layer model (aquitard in between, with discontinuities)

- Possible modeling scenarios regarding MAR methods
  1. Infiltration basin
  2. Shallow well
  3. Deeper well recharging the Lower Aquifer
**Material properties** based on laboratory measurements and geophysical measurements

- Upper Aquifer: $K \sim 1e-05$ m/s
- Aquitard: $K \sim 1e-06$ m/s (Müller et al. 2008)
- Lower Aquifer: $K \sim 5e-06$ m/s (Müller et al. 2008)

Vertical/Horizontal anisotropy: 0.1

**Initial water table** specified based on Great Plain Atlas of Hungary, 1978 and field measurements

**Boundary conditions:**

- Top boundary: annual recharge of 100 mm/year (Szilágyi et al. 2012)
- Right boundary: no flow (highest elevation)
- Left boundary: outflow based on natural hydraulic gradient: $3.4e-08 \, m^3/s/m^2$, $3.4e-09 \, m^3/s/m^2$ and $1.8e-09 \, m^3/s/m^2$ for the different layers, respectively
- Bottom boundary: no flow (*moderate recharge area, adequate outflow rate is under assessment*)

**Transient model:** 1 year (300 exponentially increasing time steps)
Preliminary results of numerical modeling using GeoStudio 2019 SEEP/W

Infiltration basin width: 100 m, water level: 1 m (constant)

Water level increase after 1 year at selected points

<table>
<thead>
<tr>
<th>Water Total Head</th>
<th>100 - 102 m</th>
<th>102 - 104 m</th>
<th>104 - 106 m</th>
<th>106 - 108 m</th>
<th>108 - 110 m</th>
<th>110 - 112 m</th>
<th>112 - 114 m</th>
<th>114 - 116 m</th>
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<tbody>
<tr>
<td>S1</td>
<td>35 cm</td>
<td>24 cm</td>
<td></td>
<td></td>
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<td>S2</td>
<td>41 cm</td>
<td>55 cm</td>
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<td></td>
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</tr>
<tr>
<td>S3</td>
<td>41 cm</td>
<td>60 cm</td>
<td></td>
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</tr>
</tbody>
</table>
Preliminary results of numerical modeling using GeoStudio 2019 SEEP/W

**Infiltration basin**
- width: 100 m, water level: 1 m (constant)

**Well**
- equivalent amount of water ($Q \sim 2 \times 10^{-5} \text{ m}^3/\text{s}$)

Water level increase after 1 year at selected points:
- S3: 400 m 1000 m
- Basin: 41 cm 60 cm
- Well: 41 cm 59 cm

→ Similar results (due to no flow boundary at the bottom + sloping terrain)
9. Conclusions

- The research area **can be suitable** for using Managed Aquifer Recharge methods
- Possible methods: surface infiltration, shallow wells and deeper wells
- With the modeled infiltration basin, water level can be increased by 0.5 m in 1 year
- Groundwater flow regime can influence MAR possibilities, thus it **must be considered**
- **Local scale solutions** could ease the water shortage of this area

**Further research aims:**

- Scenario models for different MAR solutions
- A more detailed geological and hydrogeological study in the area → validation of modeling results
- (Rain)water infiltration experiments
10. References


- **Mádl-Szőnyi, J., Szabó, Zs., Silva Cisneros, C. (2019).** Recent applications and future prospects for MAR techniques in Hungary. 10th International Symposium on Managed Aquifer Recharge (ISMAR10) – Abstracts Book & Program


- **Vituki (2001-2002).** Régiók hidrológiai állapotértékelése: Duna-Tisza köze. *Budapest*
Thank you for your time!