3D modelling and management of the subsurface in Bucharest, Romania

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Bucharest City

<table>
<thead>
<tr>
<th>Location</th>
<th>SE of Romania</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinates</td>
<td>44°26′7″N 26°6′10″E</td>
</tr>
<tr>
<td>Surface</td>
<td>285 km²</td>
</tr>
<tr>
<td>Green surface</td>
<td>20 km²</td>
</tr>
<tr>
<td>Population (2011)</td>
<td>1 942 254</td>
</tr>
<tr>
<td>Altitude (MSL)</td>
<td>90-60m</td>
</tr>
<tr>
<td>Administrative subdivisions</td>
<td>6 subunits</td>
</tr>
</tbody>
</table>

![Map of Bucharest City showing sectors and administrative subdivisions]
River Dâmbovița – extensively channelized - works during 1976-1980

Subway Station Eroilor - interior and exterior works

Earthworks of Dâmbovița River and the execution of the subway between 1976-1981

WWTP Glina

Bucharest City

Bucharest
Streets
Surface waters
Drain along Dambovita River

0 1 2 km

Bucharest
Drain
10km
7km

Superficial Deposits

River Dâmbovița

Colentina Aquifer

Ballast
Earth fill
Gravel
Clay
Trench limit
Groundwater level

Main sewer collector

Subway Tunnel

Drain

Surfaced waters

Drain along Dambovita River
### Bucharest City – 3D Geological Model

<table>
<thead>
<tr>
<th>Boreholes</th>
<th>Depth (m)</th>
<th>Depth of investigation (m)</th>
<th>Geological profiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1800</td>
<td>15 - 270</td>
<td>200</td>
<td>33</td>
</tr>
</tbody>
</table>

**Methodology**

Lithostratigraphical correlation to delineate hydrogeological units
Hydraulic characterization of the hydrogeological units

- Geospatial hydrogeological database
  - Pumping tests data
  - Complex lithology
    - Simplification tools
      - Basic lithologies $K_{\text{mean}}$
  - Statistical analysis
    - Basic lithologies $K_{\text{mean}}$
    - Simplified lithology/equivalent $K_s$ & $K_v$
  - Punctual values
    - Kriging

Spatial Distribution
- $K_s$ Mostistea
- $K_v$ Mostistea
- $K_s$ Intermedairy Deposits
- $K_s$ Colentina
Geological model intersection with the existing urban infrastructure elements
The position of the sewer conduits and their potential hydraulic connection with the aquifer strata
Urban hydrological conceptual model of Bucharest city

- Morii Lake
- Earth made Dam
- Green areas
- D/A: Influent/Effluent
- Aquifer
- Cut-off wall
- Sewer
- Drain
- Water supply conduit
- Piezometric level

Symbols:
- S: Surface run-off
- P: Precipitation
- ET: Evapotranspiration
- IP: Infiltration from precipitation
- EF: Exfiltration
- IF: Infiltration

Legend:
- Yellow circle: Sewer
- Blue square: Drain
- Green circle: Water supply conduit
- Dashed line: Piezometric level

Constructed Areas:
- Dambovita river
- Tunel
The total contribution of the groundwater infiltration into the sewer system registered at WWTP of Glina is 0.92 m³/s.
• Identification of sewer segments susceptible to groundwater infiltration

• Identification of sewer segments susceptible to sewage exfiltration into groundwater
Immersed sewer segments

- **16.9km (3.5%)** of sewer conduits are **totally immersed** in groundwater

- **79.8km (16.5%)** of sewer conduits are **partially immersed** in groundwater

More than **20%** of the modeled sewer system is completely or partially immersed in groundwater
Local hydrogeological studies

1. Scenarios to simulate urban city lake disturbance

- Construction works of a 18-storey building (72 m height) with a deep foundation (about 18 m) - proximity of Circului Park, dewatering works started - lowering the groundwater level of the shallow aquifer (Colentina).

- In 2007 (after the works have started) was observed that the water level in the lake started to decrease.
Local hydrogeological studies

Hydrogeological model simulation scenario - summer 2006-2013

Water level in Lacul Circului

Aquifer recharge

Loses from the water supply network

Recharge from precipitations

Exfiltrations from the sewer system

Aquifer descharge

Period

[mdNMN]
Local hydrogeological studies

2. Deep foundations barrier effect

- Increase of groundwater level upstream the foundation,
- Decrease of groundwater level downstream the foundation,
- Changing the groundwater flow direction due to the local changes of groundwater level.

Construction of three buildings: Tower - 2S+P+11E+Et; Paravane 2S+P+11E+Et, H - 2S+P+7E+Et., Splaiul Unirii nr. 175
Local hydrogeological studies

3. Groundwater monitoring system design

Hydraulic head maps

Colentina aquifer

Mostistea aquifer

WWTP Glina
Local hydrogeological studies

3. Groundwater monitoring system design

Monitoring and control wells location identified by the groundwater flow and contaminant transport modelling

Scenario 1: Active dewatering system near storm basin

Scenario 2: Inactive dewatering system near storm basin
Local hydrogeological studies

3. Groundwater monitoring system design

<table>
<thead>
<tr>
<th>Aquifer</th>
<th>Monitoring well</th>
<th>Control well</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conlentina</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Mostistea</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>13</td>
<td>2</td>
</tr>
</tbody>
</table>
Local hydrogeological studies

2 buildings affected by subsidence
Conclusions

- A reliable groundwater management in urban areas can be performed only by using modeling.

- The models can provide accurate results if they correctly reproduce the hydrogeological processes.

- Tools and methodologies should allow the representation in three dimensions of the geological record heterogeneity and of its spatial distribution as well as the interaction of the groundwater with the urban infrastructure.

- If the models exist, we have to take them into account. If they do not exist, they have to be developed.
Thank you for your attention!