The TOPSOIL project – Integrated approach of near surface geophysics and groundwater modelling

Helga Wiederhold(1), Mohammad A. Rahman(2), Michael Grinat(1), Reinhard Kirsch(2) & Wolfgang Scheer(3)

(1) Leibniz Institute for Applied Geophysics, Hannover, (2) Institute of Geoscience, Kiel University, Kiel, (3) LLUR, Geological Survey Schleswig-Holstein, Flintbek

Motivation: contribution of geophysics to sustainable development

In 2015, 17 goals for sustainable development were defined by the UN leading to challenges for policies and science. Earth science can contribute to the goals access to clean water (6) and energy (7), protection of life on land and under water (14,15), and immediate actions against climate change (13). In this context soil and water resources are investigated in the EU INTERREG TOPSOIL. Fieldworks are carried out in 16 pilot areas in the North Sea region in which 24 project partners from Denmark, Germany, The Netherlands, Belgium and UK are involved (Fig. 1). Two of the German pilot areas (GE-1, GE-2) under the responsibility of LIAG, LLUR (northern area) and LEBG (southern area) are situated at opposite sides of the river Elbe. Topic of this poster is the northern area GE-1 in the German state Schleswig-Holstein.

Overall Aim: To understand the dynamic of a freshwater body in the “Münsterdorfer Geestinsel” and the dynamic of shallow freshwater lenses in the surrounding marsh region with regard to sustainable groundwater management.

Project area Störmarsh: general geology, local problems and need for prognostics

The Störmarsh is located between the rivers Stör and Elbe, about 50 km northwest to the City of Hamburg (Fig. 3). Due to influence of the North Sea tides the water of the river Elbe is brackish. Most of the region is a flat marshland area with terrain heights of a few meters above or even below msl. The northern part of the area is dominated by a hilly island like moraine, the “Münsterdorfer Geestinsel”. The shallow underground of this Geest core is composed of glacial sand and till, while the shallow underground of the marsh part consists of fine grained clayey marine sediments (Klei) underlain by sand. In the Störmarsh area the TOPSOIL project is focused on the future development of the groundwater system under the influence of climate change, especially on: 

• groundwater level 
• intrusion of brackish water from the river Elbe 
• freshwater occurrence in brackish areas.

The work flow for the investigations is shown in Fig. 2.

Geophysical fieldworks and construction of the geological model are in progress. First results of resistivity measurements are presented here, further measurements (reflection seismic, NMR) are in preparation.

Development of a groundwater (GW) model for the study area is one of the major activities in TOPSOIL project. The calibrated and validated model will support to analyse salinization process and its impact on the subsurface environment. Therefore, GW model will facilitate the stakeholders to safeguard the fresh water availability from salinization and to prepare long-term groundwater management strategy (Fig. 2).

The GW model will combine several sub-surface investigation techniques (e.g., geophysical survey, isotope analysis, geological models etc.) to account for the hydrogeological heterogeneity in a regional context. To represent a complex GW catchment area where several stress factors such as salinity intrusion or groundwater withdrawal are prominent, an extensive amount of hydrological and hydrogeological data (e.g., aquifer architecture and properties, recharge, salinity distribution etc.) will be gathered. Major activities that have been planned for the GW model development are:

- Geophysical field survey to understand the aquifer structure and properties.
- Borehole information to determine aquifer extension (horizontal and vertical).
- Water quality data interpretation to identify potential contamination.
- HEM data interpretation to demarcate horizontal and vertical salinity distribution.

Besides these primary studies, the additional information for model development will be filled with secondary data such as rainfall, GW level, river and drainage network etc.

Geophysics: from resistivity to subsurface structure

The TOPSOIL area GE-1 is covered by a helicopter-borne electromagnetic (HEM) survey flown in the scope of the BGR project D-AERO (Siemann et al. 2012) leading to the resistivity distribution down to 80 m (Fig. 4).

In the resistivity map (Fig. 3) sandy soils in the Geest area are indicated by higher resistivities (blueish area, Fig. 3b), while the clayey marine sediments in the marsh show lower resistivities in the range of 10 – 20 Ωm. In the deeper depth range (Fig. 3c) two elongated low resistivity structures are identified stretching parallel to the edges of a salt dome. It is assumed that originally deeper seated clay blocks are uplifted by the salt movement. Seismic reflection measurements are planned to verify this.

The low resistivity spot in the north-eastern part is caused by saline water pumped to lower the groundwater table for open pit chalk mining (Fig. 3c).

To enable a higher resolution in the near surface depth range, geoelectrical measurements were carried out in the marsh region (Fig. 4b). The uppermost layer shows resistivities in the range of 17 – 25 Ωm, followed by a low resistivity layer (10 – 14 Ωm) down to a depth of 15 m. This is followed by a layer with resistivities of about 25 – 30 Ωm.

Drillings in the surrounding show that both near surface layers consist of marine clayey/silty material with organic components (Klei), underlain by sand. The higher resistivities of the uppermost Klei layer can be explained by the influence of vegetation and rainfall. The resistivities of the underlying sand are low compared to freshwater bearing sands (80 – 150 Ωm) indicating brackish water in the groundwater layer.

To monitor the dynamics of the brackish water intrusion in depth and time a fixed vertical electrode string chain is planned to be installed near the river Elbe.

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