EFFECTS OF CLIMATE CHANGE TO THE GROUNDWATER BODY OF THE GERMAN NORTH SEA ISLAND OF FÖHR

Helga Wiederhold[1]; Wolfgang Scheer[2]; Reinhard Kirsch[2]; Thomas Burschil[1]; Martin Lilienfein[3]
helga.wiederhold@liag-hannover.de
[1]- Leibniz Institute for Applied Geophysics (LIAG), Hannover, Germany;
[2]- State Agency for Agriculture, Environment and Rural Areas of the Federal State Schleswig-Holstein LLUR, Geological Survey, Flintbek, Germany;
[3]- AGUA GmbH, Kiel, Germany

Abstract. *The North Frisian Island of Föhr is the second largest German North Sea Island and belongs to the North Frisian Islands. The landscape is characterized by geest or moorlands (Geest) with elevations up to 13 m in the southern Part and salty marshlands (Marsch) with a very thin near surface freshwater layer in the North.*
For the drinking water supply of Föhr two water works located in the eastern and western Geest are operating making use of a freshwater lens which is developed in the saltwater environment. The production and observation wells reach depths between 20 and 80 m. Groundwater in the Marsch is salted.
Föhr is one of 7 project areas of the EU INTERREG project CLIWAT with the aim to predict the effects of climate change on the groundwater system, especially on the freshwater lens and the freshwater – saltwater boundary. The work flow in this project area was:
• geophysical and geological investigations (airborne electromagnetic SkyTEM and reflection seismic) to complete the knowledge of the underground structure
• construction of a digital 3D geological model using the program GOCAD
• construction of a groundwater flow model (MicroFEM)
• using the precipitation rate as it is expected from climate change scenarios as input parameter of the groundwater flow model and calculate the alterations of groundwater flow and local groundwater heads.
The SkyTEM survey gave an image of the saline groundwater, the freshwater lens and the internal structure of the freshwater aquifer. Reflection seismic measurements show glacial thrust structures and erosion channels which were incorporated in the geological model.
Results of the climate change modeling predict an increase of groundwater head in the decimetre range in the Geest area and an increased drainage demand in the Marsch.
Keywords: *geophysics, reflection seismic, airborne electromagnetics, geological model, groundwater model*

1. INTRODUCTION

Groundwater is an underestimated aspect in the climate change discussion (Green et al 2011). Within the EU Interreg project CLIWAT several coastal areas in the southern North Sea Region were investigated concerning groundwater and climate (Harbo et al. 2011). One project area was the Island of Föhr (Fig. 1). For a better understanding of the groundwater body a geophysical survey programme was conducted including airborne electromagnetic and seismic reflection methods. Finally a groundwater model was set up demonstrating the impact of climate change on groundwater and surface water systems and showing the consequences.

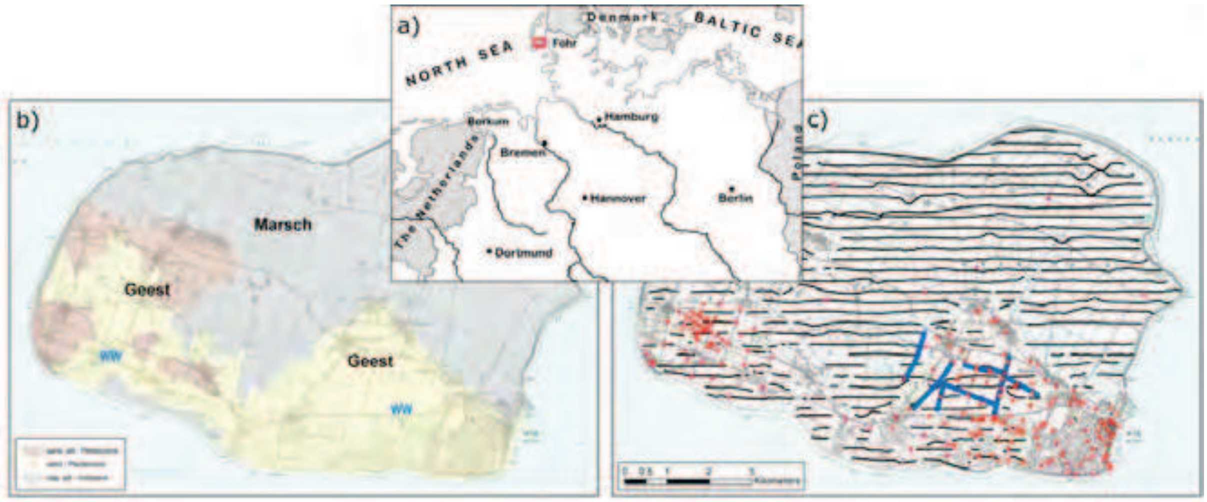

Figure 1. Location map of the North Frisian Island of Föhr (Germany); a) overview map, b) geology and location of water works (WW), c) geophysical surveys and boreholes (black: SKYTEM flight lines, blue lines: seismic reflection profiles, red dots: boreholes).

2. CLIMATE CHANGE IN THE NORTH SEA REGION

According to climate change scenarios we expect for the German North Sea coastal area an average annual increase in temperature of +2.8°C and in precipitation of +6% whereby the seasonal distribution changes are enormous with -19% in summer and +25% in wintertime (www.norddeutscher-klimaatlas.de, last access 30.04.2012). Additional to this a sea level rise of nearly 1 m by 2100 is expected.

3. METHODS AND DATA

With the beginning of the CLIWAT project the knowledge of the underground of Föhr was restricted to the areas of the two water works in the western and eastern Geest where many boreholes and wells exist (Fig. 1c). With the CLIWAT project the knowledge was enhanced by an airborne electromagnetic survey (EM), i.e. SkyTEM, and seismic reflection profiles (Burschil et al. 2012a, b). The seismic sections display glaciotectonic thrust-faults and buried glacial valleys as well as the depth of Quaternary sediments (Fig. 2). The resistivity maps from the SkyTEM survey show the direction and extent of the thrust-fault complex, the spatial extent of the freshwater lens, the freshwater-saltwater boundary, as well as groundwater outflow to the sea and to the Marsch (Fig. 2). The results were integrated in a 3D geological model with GOCAD software.

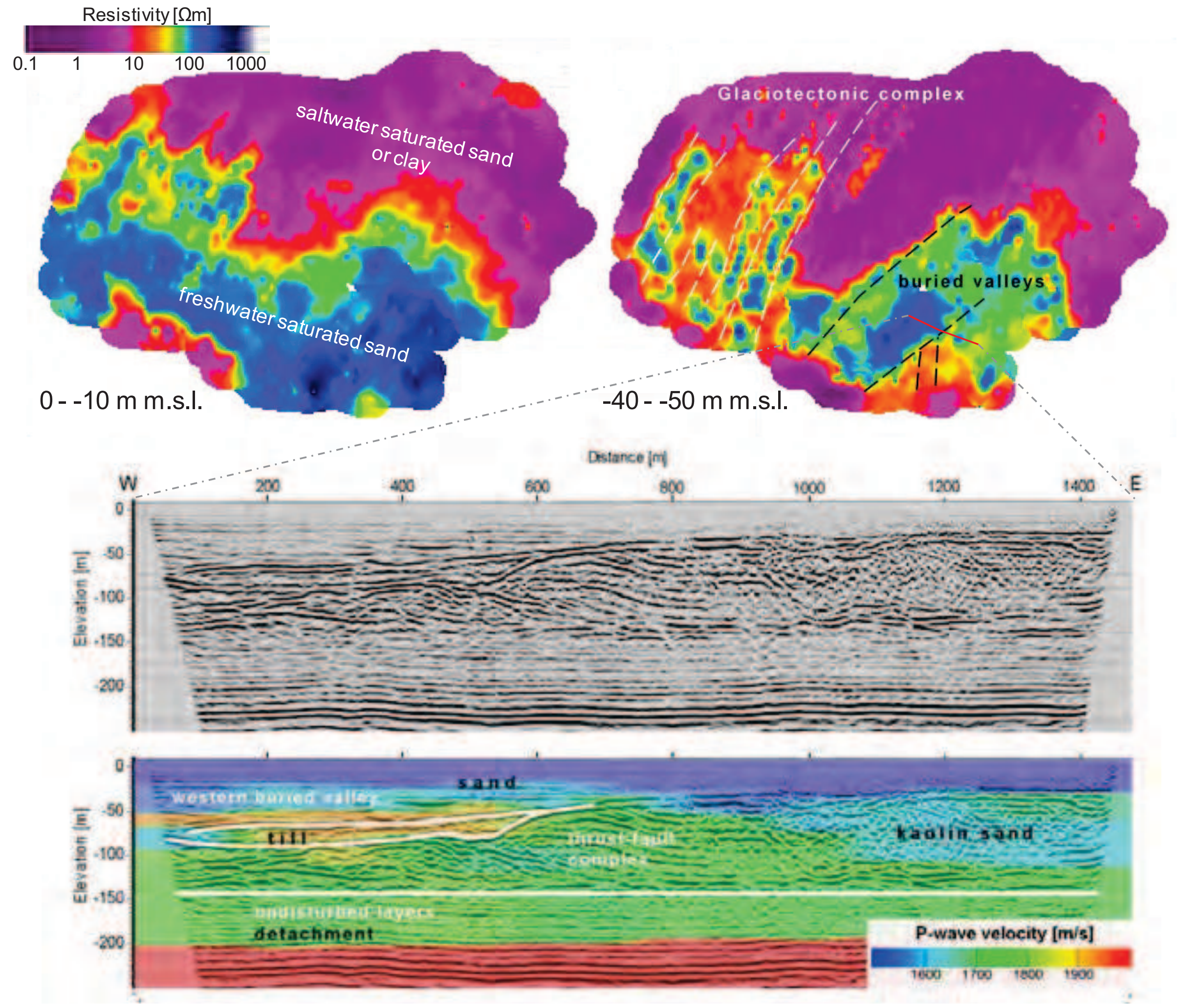

Figure 2. Resistivity distribution from airborne electromagnetics for two depth ranges (top) and seismic section without and with interpretation (bottom).

4. THE GROUNDWATER MODEL

Besides the geological model further information is required: extent and connection of the aquifer, connection to the runoff ditches, surface water drainage systems, and groundwater recharge. The groundwater modeling is done using the 3D finite-element model MicroFEM. The model comprises the island including the surrounding tide flat. The model includes 6 aquifer and 6 aquitards and an impermeable base horizon. The current situation is based on hydrological data from 2001 to 2010. Predictions for 2100 are based on IPCC climate scenario A2 and are added to the current situation (LLUR 2012).

5. RESULTS

The modeling results give hints on the magnitude of future changes in the water balance (Fig. 3). In the Geest increasing precipitation leads to higher groundwater recharge and to a moderate rise of the water table. The freshwater-saltwater transition in the coastal area will move. In the Marsch two topics will be relevant in future: 1) definitely more surface water needs to be drained, 2) the rising sea level will lead to a rising saltwater level and increasing saltwater intrusion into the upper aquifer. Adaptation of infrastructure concerning water handling will be necessary. Especially concepts for monitoring saltwater intrusion are needed as well as concepts for retention of freshwater in the Marsch to counteract a rising saltwater level.

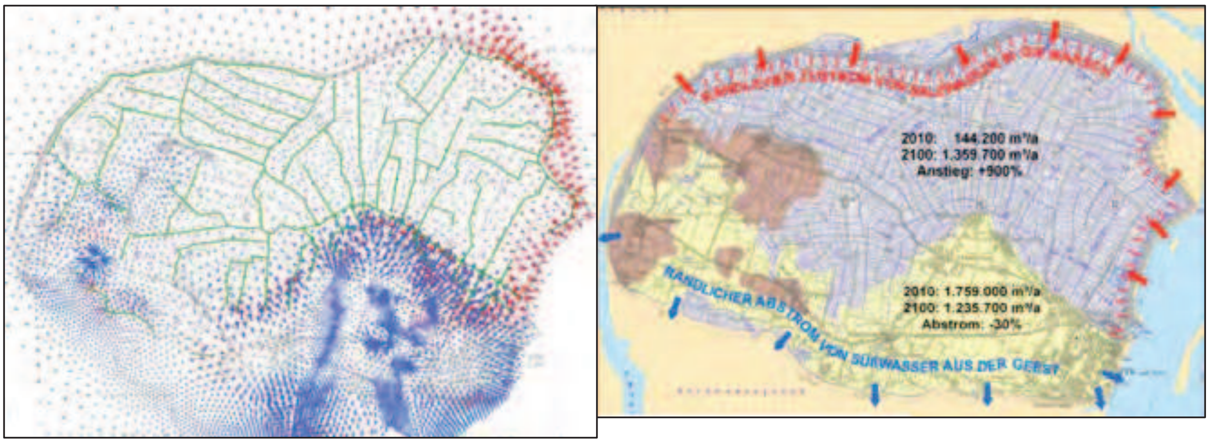

Figure 3. Left panel: Groundwater flow in the upper aquifer (direction and magnitude), blue: 2010, red 2100); right panel: island boundary: Saltwater intrusion into the Marsch (red) 900% increase by 2100 and freshwater runoff out of the Geest (blue) 30% decrease by 2100.

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