Midterm Catalogue

Topsoil

Resilient soil and water resources, understanding the water beneath your feet

Colophon

The Topsoil mid-term catalog is published by Region Midtjylland and compiled by the partners of the Topsoil project.

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You can download the publication at
https://northsearegion.eu/topsoil

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Foreword

Climate change affects the hydrological cycle and we now experience more heavy rains and increasing sea levels. The changes in climate also affect the groundwater aquifers – the water beneath our feet.

The Topsoil project explores the possibilities of using the topsoil layers to solve current and future water challenges concerning water quantity and quality. It looks beneath the surface of the ground, predicts and finds solutions for climate related threats like flooding during wet periods and droughts during summer seasons.

The overall objective of the project is the joint development of methods to describe and manage the uppermost 30 m of the subsurface, in order to improve the climate resilience and protect the environment of the North Sea Region.

Across the North Sea in Northern Europe we share different challenges within ground water and climate change. In a 3½ year European project we have adressed five shared challenges via geological, geophysical and hydrological investigations, stakeholder involvement and changes in management.

In 16 pilot areas we have developed and tested solutions for managing the uppermost 20-30 m of the subsurface. In this leaflet summaries of all pilots and an overview of the methods used are included. The work in the different countries will lead to a strong improvement of climate resilience in and across pilot areas.

We hope you enjoy the reading.

Sincerely
The Topsoil Partnership

Durham Autumn Conference - October 2018

Content Table

Our five challenges

Across the North Sea Region we share different challenges within groundwater, surface water and climate changes. In this project five shared challenges identified.

1. **Flooding** in towns and agricultural areas due to the rising groundwater table caused by changed precipitation patterns.

2. **Saltwater intrusion** into freshwater reserves due to rising sea levels and changed irrigation, drainage and drinking water demands.

3. The need for a **groundwater buffer** to store water in periods of excess rainfall. The buffer of fresh water can be used for irrigation purposes during dry periods.

4. Better knowledge and management of **soil conditions**, which will provide better resilience to extreme rainfall events, improve water quality and improve crop yields.

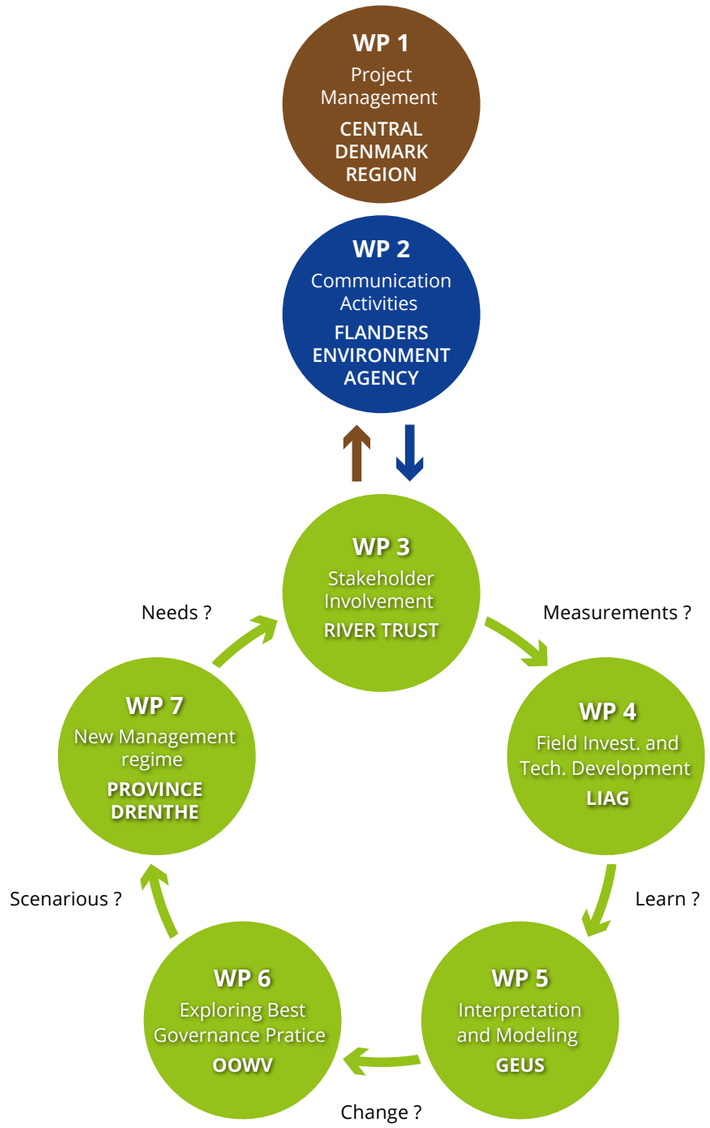
5. The **capacity to break down** nutrients and other environmentally hazardous pollutants in the uppermost layers is yet unexplored. By improving our understanding, better landmanagement can be implemented.

The adjacent table gives an overview of challenges addressed in the respective pilot projects.

The table also contains other overall aspects of the pilots:

- Groundwater and/or surface water
- Field scale and/or catchment scale
- Real data and/or model calculations

Pilot	Challenge					Water		Scale		Data	
	Flooding	Satlwater intrusion	Groundwwater buffer	Soil conditions	Breakdown capacity	Groundwater	Surface water	Field scale	Catchment scale	Real data	Model calculations
BE1		✓	✓	✓	✓	✓				✓	✓
BE2	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
DK1	✓		✓	✓	✓	✓			✓	✓	✓
DK2A	✓			✓	✓	✓	✓	✓		✓	✓
DK2B					✓	✓	✓	✓		✓	
DK3			✓	✓	✓	✓		✓			✓
DK4	✓	✓	✓		✓	✓		✓		✓	✓
GE1	✓	✓	✓			✓		✓	✓	✓	✓
GE2		✓	✓	✓		✓			✓	✓	✓
GE3	✓	✓				✓			✓	✓	✓
GE4			✓			✓			✓	✓	✓
GE5				✓	✓	✓		✓		✓	✓
NL1A		✓	✓	✓		✓		✓	✓	✓	✓
NL1B				✓	✓		✓	✓	✓	✓	✓
NL2				✓	✓	✓	✓	✓	✓	✓	✓
NL3	✓	✓	✓	✓		✓			✓	✓	
UK1	✓			✓		✓	✓		✓	✓	
UK2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓



Work Packages

WP1

Project management

The Topsoil project is a large project involving 16 pilot areas and 23 beneficiaries in 5 countries around the NSR.

The project is organized in 7 work packages reflecting the different components to be delivered within the project and a work package concerning project management headed by the lead beneficiary.

A leader of the individual work packages has been appointed to reflect the specific top competences of the organizations and to spread the leaderships geographically. On the daily basis Central Denmark Region organizes the project, supported by the steering group with the lead beneficiary, coordinating beneficiary in each country and the work package leaders. The steering group meets in person half yearly to ensure progress and solve challenges. In addition, they organize a telephone conference every second month.

In the 5 participating countries, country steering groups were formed and continue the work during the project period. To ensure a transnational outreach, a transnational group of stakeholders is established in a board. All beneficiaries meet twice a year to ensure transnational progress, learning, synergies, evaluation and involvement of all partners in the project.

Central Denmark Region is responsible for Work package 1.

Partner meeting Bruges – September 2017

WP2

Communication

The pilot projects play an important role in providing the necessary evidence base, and provide an additional opportunity to interaction with the general public. The objectives of this WP are: to communicate the objectives, results, benefits and demonstration projects that are achieved and implemented to water managers across North Sea Region to facilitate the uptake of measures and interaction with the general public and stakeholders in the different pilot project areas.

For this, Topsoil invites key stakeholders with specific expertise take part to and contribute to transnational partner meetings and pilot activities, thematic workshops on project challenges, governance challenges and field trips to discuss pilot implementations (see also WP3). The Topsoil-message is spread via multiple 'tools', such as the webpage, social media, videos and press releases. Adressing issues relevant to adapted groundwater management, several transnational workshops were organized so far (and there will be plenty more) to inform and involve stakeholders from local and regional to European level.

Flanders Environment Agency is responsible for Work package 2.

Workshop nutrients and agriculture Zeegse – September 2018

Stakeholder involvement

It is increasingly apparent that for projects aiming to develop improved long-term sustainable management solutions stakeholder participation is required at the design, implementation and evaluation phases.

Rivers Trust as a coordinator will in cooperation with relevant beneficiaries provide a framework for ensuring a high level of stakeholder participation in all project phases. Key objectives to achieve this include;

- Develop an appreciation for the importance of stakeholder participation within each pilot and familiarization with appropriate participatory methods and approaches
- Identify key stakeholders at pilot and project level and involve them in project activities.
- Develop a framework for both planning stakeholder participation and critically evaluating the success of each pilot and the project at involving stakeholders.
- Collate and disseminate information relating to the approaches taken throughout the project and the impact they may have had on developing “new thinking” and changes to management. The work package lead will have a coordinating role in many of these activities, but each beneficiary will have an ongoing active role in developing and executing their own activities as well as collating and reporting information to the wider project group.

Stakeholder involvement is a key aspect of the Topsoil project. At the pilot level, stakeholder involvement is critical both to ensure that the pilots are delivered as planned and that the results have sufficient influence on the future management of the sites.

All pilots have produced a strategy for stakeholder involvement, detailing the key stakeholders that need to be involved in the pilot and how they will be involved. Production of the strategies was supported by the Topsoil stakeholder involvement guidance produced earlier in the project and available to download from the project website (insert hyperlink once it is on the site).

Stakeholder involvement within the pilots has included attending planning meetings, co-designing trials and field investigations, validation of conceptual models, cooperation on data collection/provision and direct contribution to pilot delivery.

At the project level, stakeholders have actively participated in project meetings and workshops, providing expert knowledge and contributing to discussions on the key challenges of the Topsoil project.

Rivers Trust is responsible for Work package 3.

WP4

Field investigation

Taking groundwater, salinization, groundwater levels, soil, interaction between vadose zone and saturated zone into the consideration of simulation models special (geophysical) techniques are needed to learn more about the subsurface. These special techniques and field investigations are applied in different pilot areas. The acquired data contribute to geological and hydrological 3D models.

Objectives are:

- Development, innovation and practical testing of newest technology with the aim to identify geological layers and soil characteristics, salinity, pathways for salinity or nutrients/pollution, hydraulic properties.
- Joint development and implementation of an investigation plan for each pilot.

The investigations are done via staff exchange and close cooperation between the lead of the pilot area and the investigation team.

This will include a Transnational Peer Review (TPR) for each pilot at the start and at various stages during the project in order to identify transnational synergies, collaborative opportunities, and maximize project delivery.

- Development and application of workflows for data processing and identification and preparation of parameters for the geological and hydrological models
- Solid climate change adaptation needs a reliable database, shared databases and dissemination of results

Structures and processes in the subsurface beneath our feet must be known for proper management of soil and water. Overview measurements like SkyTEM were carried out in some pilots and give, e.g., the distribution of freshwater and saltwater in the aquifers, while other pilots use results from airborne electromagnetic measurements by BGR (Federal Institute for Geosciences and Natural Resources) prior to the project start for an interpretation in terms of groundwater conditions. In some pilots the tTEM system newly developed by HydroGeophysics Group Aarhus University was applied to provide resistivity information in the target depth range of 0–70 m. Methods to relate the resistivity distribution in the aquifer covering layers to clay content and hydraulic conductivity for an assessment of groundwater protection and recharge are under development.

Approach and results of all activities will be published in a special issue of a scientific journal.
The reference list can be found on page 86.

tTEM system (Aarhus University)

The work is done in close cooperation with the other WPs, especially WP 3 and 5. The work builds on different knowledge and new perspectives from beneficiaries.

Leibniz Institute for Applied Geophysics is responsible for Work package 4.

WP5

Interpretation and modeling

Hydrological and geological tools will be applied and developed to prepare the basis for new management. Further development of methods that are able to map and model the geology in the shallow subsurface. These methods will be based on geophysical as well as geological and hydrogeological data that will be integrated and interpreted.

The objectives of the work package are to:

- Analyze hydrogeological data from the North Sea region on geology, groundwater and surface waters.
- To set up models of varying complexity to analyze the data and hydrogeological systems in question.
- To carry out predictions of the impact of future changes in land use, water management and climate change on water resources and groundwater quantitative and chemical status according to the Water Framework Directive. The work is joint in the TRT.

Modelling will be a tool to investigate flooding and inundation in urban and rural areas and to investigate the potential to use groundwater reservoirs as buffers to store water in periods of excess rainfall.

The expected increasing problems with salt water intrusion into coastal freshwater reserves will be further investigated through state of the art advanced density-dependent modelling tools in combination with a basic understanding of the geological structures are required to make reliable predictions of the risk of saltwater intrusion.

Further, the capacity degradation of nutrients (as well as other hazardous pollutants) in the uppermost layers will be investigated.

GEUS is responsible for Work package 5.

WP6

Governance

Topsoil aims to explore the possibilities for using the uppermost soil layers to solve present and future water challenges. However, implementing local measures is not enough. Strong governance is needed to help unify the different interests at different levels. We define water governance as the way the management of water resources is organized comprising all technical, organizational, legal, financial and political aspects, and the totality of interactions and collective actions taken by state and non-state actors.

The objectives of this WP are:

- To share knowledge on water governance models
- To develop a European governance assessment toolkit for Topsoil adaptation
- To develop regional roadmaps towards an optimal governance setting

In Topsoil, good groundwater governance is “the way of getting things done”.

Since models and information need to be supported by appropriate governance approaches, Topsoil dedicates much attention to better understand how legal frames, cooperation, and availability of resources can support the development and implementation of measures. The Transnational Governance Team developed a 2-hour workshop format which allows to identify identification of specific steps for a “roadmap”. The first workshops addressed the designation of water rights, groundwater flooding and reducing nutrient losses. Governance is also central in additional meetings the partners set up: For example, in August 2016 CDR organized a field trip for Danish stakeholders to different Topsoil pilots in Germany and the Netherlands. Further, a series of bilateral meetings between Dutch and German partners discuss in depth how to decrease the negative groundwater impact of maize growing. In these meetings, water and land managers benefit from discussion of their central issues from the perspective of the neighboring countries. Results from the workshop will feed into work package 7 (New management regime).

OOWV is responsible for work package 6.

WP7

New management regime

For each pilot a new water management plan based on the new knowledge will be developed. The management will emphasise the focus on a strong climate resilient management.

The goal is to describe new ways of managing our surface near groundwater to find resilient and sustainable management regime for Topsoil and groundwater including:

- Development of new management in each pilot
- Synthesize the roadmaps, and their impact on policy challenges per catchment area (flooding, saltwater intrusion, drought, etc)
- Identification of measures which have been in particular effective for dealing with specifcone or more policy challenges at local level, as well as barriers or potential from European level which impacted an effective implementation
- Development of recommendations for addressing the European barriers for implementing locally effienct measures

Most pilot are under process and new management plans are not ready yet. To be able to get the most relevant information out of the different management plans a format has been made in which the important content of the new management plans will be written. In the partner meeting in Durham (autumn 2018) the format will be presented.

The main content of the management plans will be discussed in a partner meeting in the spring of 2019. This will lead to a proposal for a new management regime in the NSR for managing ground water, surface water as well as the top soil, related to flooding, saltwater intrusion, drought and soil.

Together with the transnational learning of the other WP’s this will be presented in an end report. This will include proposal for solving governance issues, measures which have been effective and recommendations for addressing European barriers. The draft end report will be ready before the final partner meeting in the autumn of 2019.

Province of Drenthe is responsible for Work package 7.

Pilot Projects

BE 1

Identifying the salinization of groundwater in the (Western) Flemish coastal area by collecting airborne electromagnetic data

CHALLENGES
- Flooding
- **Saltwater intrusion**
- **Groundwater buffer**
- **Soil conditions**
- **Break down capacity**

Background and objective

Groundwater in the Belgian western coastal plain is saline by origin, making sure fresh, salt and brackish groundwater are found there. This fresh-salt distribution was mapped in the 60s and 70s and published in a so-called 'salinity map'. However, half a century later, there is a clear need for area-wide mapping of the salinization of the area. The freshwater lenses in the area are frequently used as freshwater supplies. By comparing the newly collected data with the existing salinity map, the autonomous evolution of the freshwater-saltwater distribution can provide a reference in considering the effects of climate change and sea level rise.

While laborious work was needed for the creation of the old salinization map, airborne electromagnetics (AEM) can be used today.

What have we done

We have mapped the fresh-saline distribution of the phreatic aquifer using airborne EM.

Results:
- 3D-image of the pore water conductivity
- Depth of the fresh-salt water interface

What is still to be done

Results are in review now and will be used for defining potentials for implementing measures like creek ridge infiltration (see BE 2).

Collecting airborne data – July 2017

QUALITY INDICATOR

Baseline	Number of monitoring points of the old salinization map
Target	20 % more data points
Target time	End of project
Considerations	-

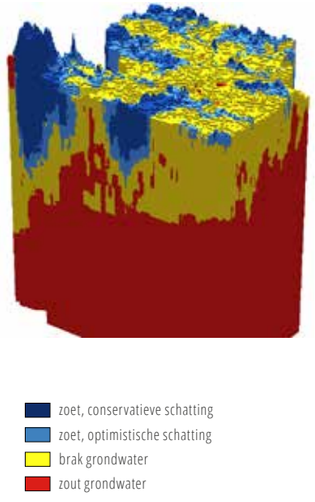
PARTNERS AND STAKEHOLDERS

Regional authorities and agencies, polder boards, farmers association

PRELIMINARY RESULTS

The Belgian pilot focuses on mapping the salinity distribution of groundwater using airborne electromagnetics and aims to look into a number of measures that could increase the availability of freshwater for agriculture in the polder area. The salinity distribution is mapped (BE1) using the SkyTEM system which is an airborne transient electromagnetic sensor that measures ground conductivity using electromagnetic waves. About 2400 line km are flown which covers the main part of the Belgian polder area. The inversion process produces bulk resistivity profiles for each flight line (Figure 1). With the aid of a lithological model, bulk resistivity is converted into a 3D image of pore water resistivity. Finally, a map showing the depth of the fresh-salt water interface will be available. A preliminary result is shown on figure 2.

New salinity map (concept)



3D result pore water conductivity

BE 2

Increasing the availabilty of freshwater for agriculture by improving local hydro(geo)logical conditions

CHALLENGES
- **Flooding**
- **Saltwater intrusion**
- **Groundwater buffer**
- **Soil conditions**
- **Break down capacity**

Background and objective

Farmers in West-Flanders make significant use of groundwater from the Paleocene aquifer (called "Landenian" aquifer) for their water supply. For years, the level of the Paleocene aquifer is decreasing, compromising the water supply through this layer. In addition, shallow water resources are scarce because of the brackish nature of the top aquifer near the coast, and the shallow occurrence of aquitards (clay layers) deeper inland. The pilot project aims to look into a number of measures that increase the availability of freshwater for agriculture in the polder area of West-Flanders. The expected impact of this pilot project is highly anticipated in the river basin management plans for Flanders. The pilot project will evaluate the possibilities for freshwater storage and aims to specify what measures can be taken to achieve this. Together with the water users and water managers, it wants to prepare a plan for the realization of one or more pilot projects that can improve the availability of freshwater

What have we done

We have mapped the fresh-saline distribution of the phreatic aquifer (see BE 1). Based on these results, potential maps are created showing the possibilities for freshwater storage. We did a workshop with stakeholders regarding the results of the airborne measurements and discussed the possibilities for implementing measures to improve the availability of fresh water. A field workshop was organized to look at valuable pilot projects.

Results:
- 3D-image of the pore water conductivity
- Depth of the fresh-salt water interface

What is still to be done

Finishing the potential maps. Preparation of a plan for the realization of one or more pilot projects.

QUALITY INDICATOR

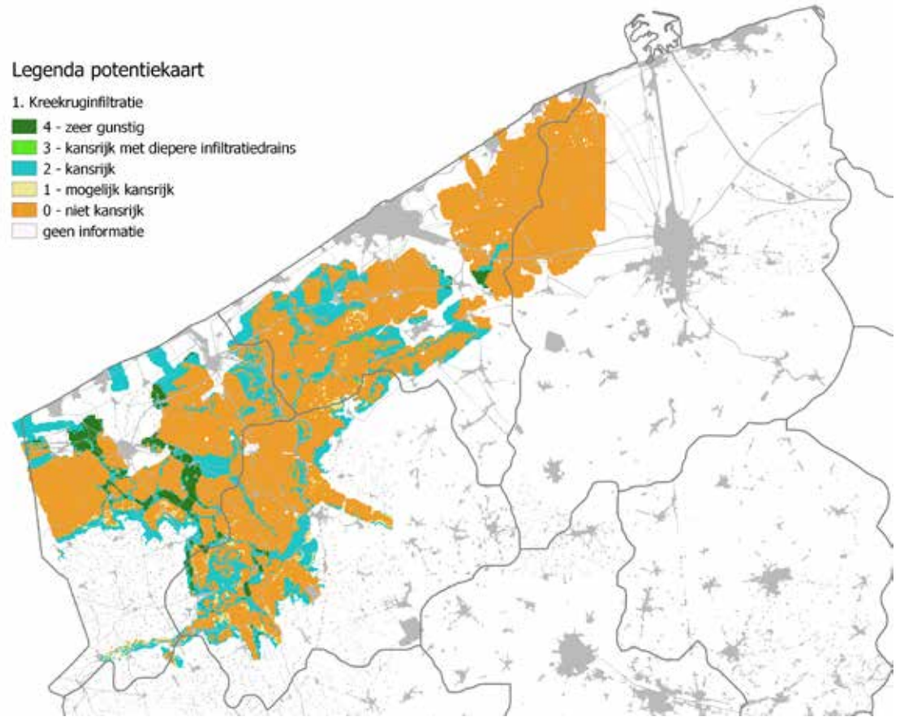
Baseline	Water demand for cattle for a specific pilot project
Target	20% of water demand for cattle for a specific pilot project will be covered by improving the fresh water availability
Target time	> 2019 (depends on realization of pilot project)
Considerations	-

PARTNERS AND STAKEHOLDERS

Regional authorities and agencies, polder boards, farmers association

PRELIMINARY RESULTS

Based on the results of pilot BE1, potential maps are created showing the possibilities for freshwater storage (figure below). We did a workshop with stakeholders regarding the results of the airborne measurements and discussed the possibilities for implementing measures to improve the availability of fresh water. A field workshop was organized to look at valuable pilot projects.



Map showing the possibilities for freshwater storage

DK1

High groundwater table in a Danish town: challenges and opportunities in a climate adaption perspective

CHALLENGES

- **Flooding**
- Saltwater intrusion
- **Groundwater buffer**
- **Soil conditions**
- **Break down capacity**

Background and objective

The aim of this pilot is to better understand the challenges connected to the fluctuation of the groundwater table. The town of Sunds is located on a meltwater outwash plain formed under the last Ice age and today it is dominated by agricultural areas. The groundwater table in the town and the surrounding areas is very close to the surface and reacts very fast to increasing rainfall. Due to renovation of sewage pipes and increasing precipitation, the area prone to flooding caused by rising groundwater levels. The quality of the excess water differs. In some areas, the water quality is good, while in others areas the quality of the water is poor due to pollutants.

Possible actions to take against future groundwater flooding is investigated by new methods and by introducing knowledge from other partner countries with expertise within this field. This will lead to climate change adaption plans which will be established, tested and introduced to the relevant stakeholders.

The Water Sector Act set framework for the water companies. It is not allowed to make a system, where the water company stands for the whole water circuit today. We need a change in national legislation to make it legal. A solution could be a 3. string for groundwater.

What have we done

- Groundwater quality investigation
- Walk TEM, GCM and DCIP measurements
- tTEM and FloaTEM measurements
- Geological interpretation and modelling
- Attention on the needs for a change in national legislation

What is still to be done

- Groundwater modelling
- Climate scenario simulations
- Development of action plan, stakeholder involvement
- New management plan

QUALITY INDICATOR

Baseline	Number of private basements in Sunds flooded after renovation without any actions - will be calculated from the groundwater model.
Target	20 % reduction in the number of flooded private basements in Sunds
Target time	Depending on modelling results and possible solutions
Considerations	-

PARTNERS AND STAKEHOLDERS

Topsoil partners:
Herning Municipality
Central Denmark Region
Aarhus University
GEUS
External partners:
Herning Water Company
Local home owners association
Stakeholders:
Landowners

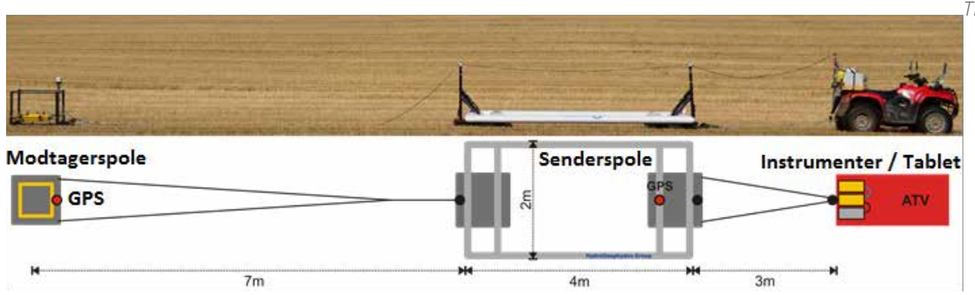
PRELIMINARY RESULTS

To counter for the climate change challenges with rising groundwater a detailed 3D geological model has been established and will feed into a groundwater model. With the groundwater model it will be possible to simulate future climate scenarios and thus to assess a number of possible actions that can taken to prevent the groundwater flooding.

The 3D geological model is mainly based on geophysical data – tow-TEM (tTEM). tTEM is a new geophysical method developed in Topsoil by Aarhus University. It was tested on fields located North, south and east of Sunds lake. It was also further developed and tested on Sunds Lake (FloaTEM). The configuration of the system is shown in the figure below.

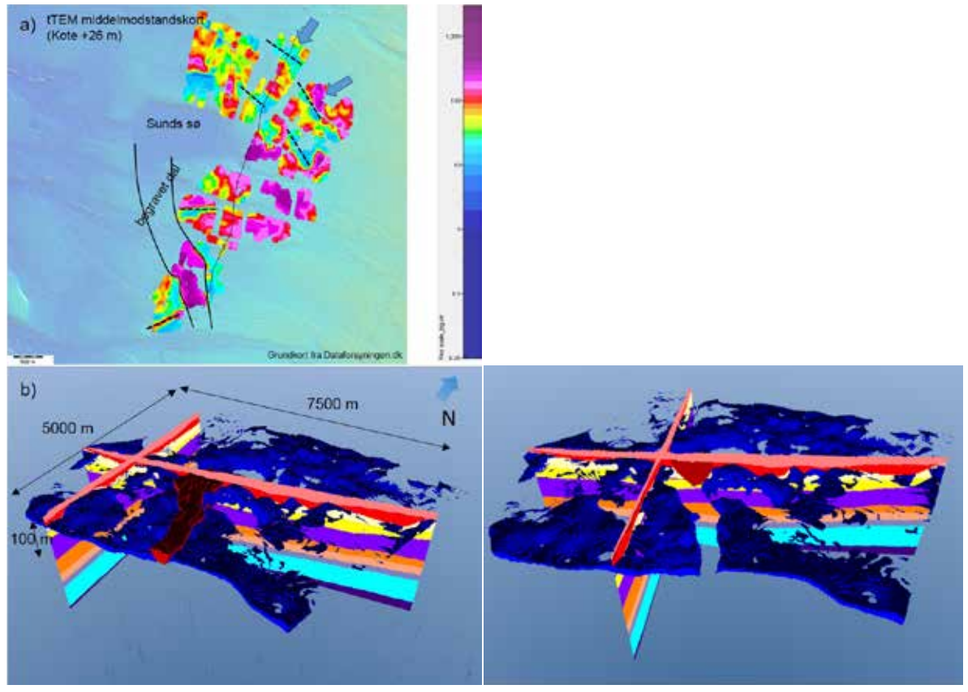
The geophysical data has revealed a complex geology underneath a 5-15 m thick cover of meltwater sand deposits. The figure below shows the distribution of an important Miocene clay layer in the area. The clay layer is heavily deformed by glacial tectonics and is expected to have a huge impact on the near-surface groundwater flow system in the area.

The

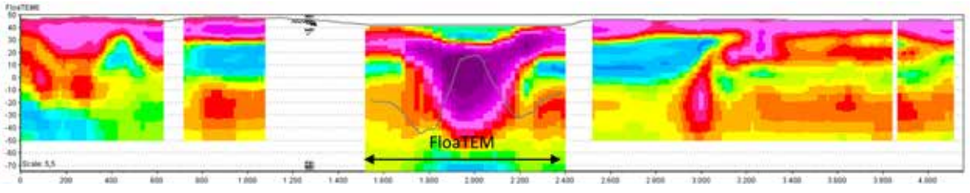


tTEM system

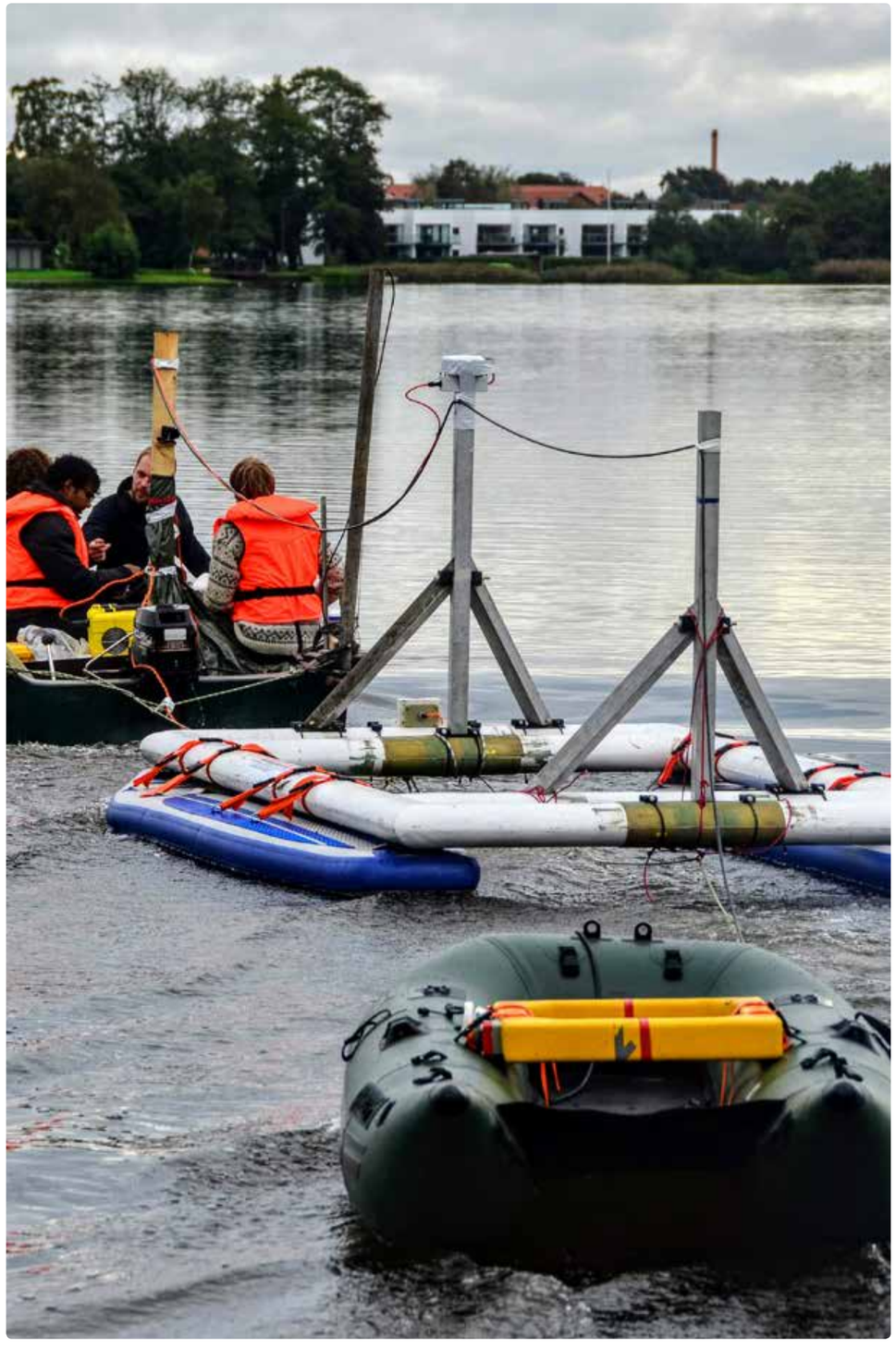
The FloaTEM data from the lake gives in combination with the landbased tTEM data an exciting insight into the possible formation of the lake. As showed in the figure below more than 20 m thick sequence of organic lake deposits (gyttja) in the lake indicate local subsidence, which likely has initiated the formation of the lake. It is expected from the geological interpretations that the upper groundwater table under the town of Sunds is in hydraulic contact with the lake water. The groundwater modelling will improve understanding of this and other local hydrogeological aspects.



3D view of the constructed geological model. Blue is showing the deformed Miocene clay layer.



Cross section through Sunds lake. Blue and green colors represent fine-grained sediments such as gyttja and clay. From 1500 to 2400 meters on the profile FloaTEM data reveal up to a more than 20 m thick sequence of organic lake deposits (gyttja).



DK2A

Targeted regulation of fertilizers to obtain sustainable intensification. Investigating the potential for natural break-down of pollutants in the subsurface groundwater

CHALLENGES

- **Flooding**
- Saltwater intrusion
- Groundwater buffer
- **Soil conditions**
- **Break down capacity**

Background and objective

To meet the targets in the Water Frame Directive, plans are made for the aquatic environment. Nitrogen leaching must be reduced in several areas to reach good conditions in the aquatic environment.

The overall objective of the project is to investigate whether increasing the fertilizer allocation on less vulnerable soils and reducing the allocation of fertilizers to vulnerable soils, can enable the farmer to achieve greater yields while reducing the overall leaching of nitrogen into surface water and groundwater. The studies include both the current climate and a future climate with expected 40 % increase in nitrate leach in 2100 due to more frequent and more heavy rainfall.

What have we done

- Digitalization of drainage network layout plans
- Drain water samples
- Drain water flow measurements
- Precipitation measurements
- Ground conductivity meter mapping
- Gradient magnetometer measurements
- tTEM measurements
- N-min sampling
- Biomass maps
- Yield measurements
- Geological model

What is still to be done

- A conceptual groundwater model
- Dialog with farmer organisation regarding measures

QUALITY INDICATOR

Baseline	Present nitrogen balance is calculated on the basis of drain water flow measurements and drain water samples.
Target	20 % nitrate reduction in flux of water drains and recharge in a future climate by innovative management
Target time	2100
Considerations	Weather conditions prior and post seeding has a major impact on crop establishment as well as on nitrate leaching. Water retention in soil depends on content of organic material in soil and soil structure.

PARTNERS AND STAKEHOLDERS

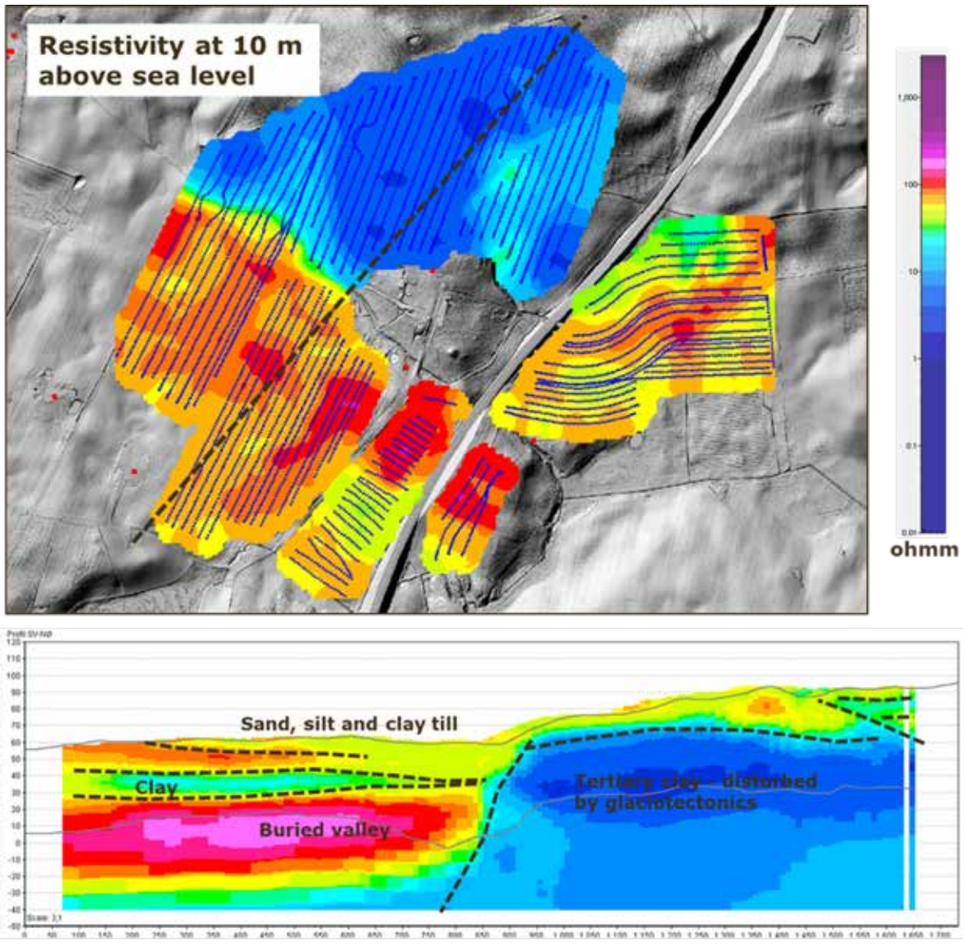
Topsoil partners:
Horsens Municipality
Central Denmark Region
Aarhus University
External partners:
Go-Gris I/S
Stakeholders:
Landowners
LMO Agriculture consultancy

PRELIMINARY RESULTS

Ground conductivity meter mapping displays the distribution of clay and sand content in the Topsoil. The GCM map may be converted into a JB type map for the field. Yield measurements indicates that clay rich soil give the highest yield—most likely because clay rich soil is less effected by water shortage.

N-min measurements from early autumn to early spring enables an estimate of the amount of N-min that has been leached out pr. hectare in the period. Measurements of the drain water shows that the majority of nitrate leaching through drains is in the period October-March. In this period drain flow is high and nitrate content in drain water peaks at low temperatures.

tTEM measurements has mapped the soil resistivity to a depth of 40-50 meters below terrain resulting in a 3D resolution of the geology—see profile example below. This will be used for a conceptual model to estimate the hydrologic conditions in a future climate.



tEM data coverage and a profile section showing the complex geological setting on the fields

Improvement of traditional investigations by prior geophysical investigations

CHALLENGES
- Flooding
- Saltwater intrusion
- Groundwater buffer
- Soil conditions
- **Break down capacity**

Background and objective

Traditionally, contaminated sites are investigated by drillings, soil- and water samples and soil gas measurements. Sampling points are based on potential existence of point source pollutions detected from historical archives, by interviews etc. Based on the first examinations subsequent point data are acquired in order to delineate the hotspot and/or plume. This approach contains a substantial uncertainty especially in a heterogeneous geological setting, thus a solid risk assessment implies a large number of point data.

The objective of this pilot is to clarify if expenses and/or time can be reduced by adding geophysical measurements prior to the point approach. The trial is carried out on a former landfill and two agricultural contractors, where pollutions with leachate and pesticides have been proved. The final output should be recommendations and guidelines for a better integrated practice resulting in better risk management.

What have we done

- Traditional investigation proposals
- GCM measurements
- T-TEM measurements
- Investigation proposals based on geophysical data
- Field investigations involving boreholes, soil air measurements and water samples

What is still to be done

- Supplementary field investigations
- Modelling at one case study
- Assess climate change impact
- Evaluation of concept

QUALITY INDICATOR

Baseline	Baseline for costs and number of point data per site are defined by CDR average costs and numbers for investigations in the period 2010-2018
Target	20 % cost reduction on traditional investigations of point source contamination
Target time	2021
Considerations	Geophysical measurements prior to investigation proposals will optimize number and placement of traditional point data. Depending on the geological setting and complexity traditional point data may be reduced or expanded accordingly.

PARTNERS AND STAKEHOLDERS

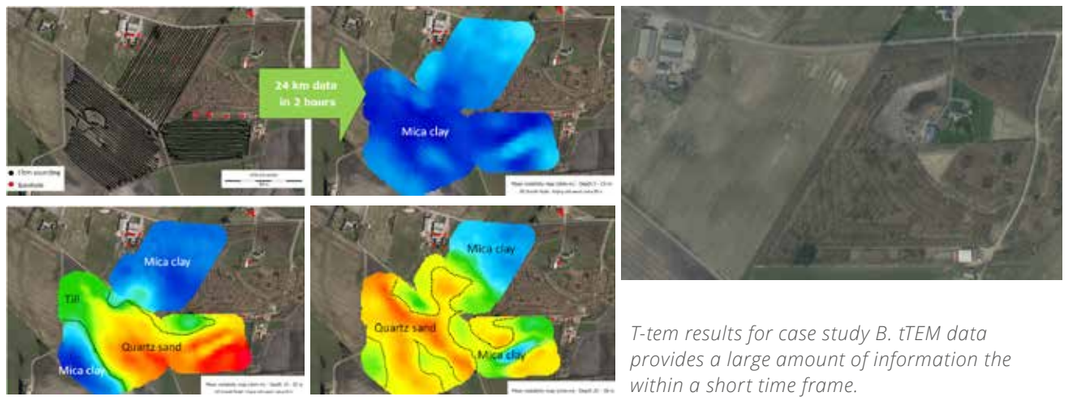
Topsoil partners:
Central Denmark Region
Aarhus University
External partners:
NIRAS (Consultancy)
Rambøll (Consultancy)
Stakeholders:
Landowners
Contact details:
John Ryan
johpee@rm.dk

PRELIMINARY RESULTS

t-TEM mapping has so far proven as a relevant and strong tool for pollution mapping and vulnerability mapping. The method provides high 3D resolution of the shallow subsurface and is relevant on field scale. So far results indicates that geophysical mapping with tTEM prior to in depth investigations may optimize placement and/or number of boreholes.

A: Landfill leachate threatens the local drinking water abstraction. tTEM mapping indicates potential dispersal pathways allowing an optimized siting of boreholes.

B: An agricultural contractor has caused a pesticide contamination that threatens the local drinking water abstraction. tTEM mapping indicates a coherent micaceous clay layer that will reduce the need of boreholes substantially as the mica clay layer will retain pesticides in the upper aquifer.
C: An agricultural contractor has caused a pesticide contamination that may or may not threaten one or more local drinking water abstractions. tTEM mapping indicates a thin clay layer in the upper layers of a buried valley. This clay layer has turned out to be decisive for the risk assessment.



T-tem results for case study B. tTEM data provides a large amount of information the within a short time frame.

DK3

Development and testing of high resolution near-surface methods for improved groundwater vulnerability assessment (Varde)

CHALLENGES

- Flooding
- Saltwater intrusion
- **Groundwater buffer**
- **Soil conditions**
- **Break down capacity**

Background and objective

The town of Varde is located in the southwestern part of Jutland. The area suffers from lack of clean ground water. Very often nitrate and pesticides pollute the known aquifers and it has for many years been difficult to find new clean aquifers. Recent investigations show that the area is heavily glacially deformed with thrusting and folding of the subsurface. This means that gateways for pollution along these structures to the aquifers frequently exist in the area. Due to the presence of the complex geology a new high-resolution mapping method is needed. New ways of data interpretation and modelling of dense data also has to be developed to make detailed vulnerability assessments. A thorough understanding of the subsurface supported by new mapping methods (Tow-TEM) will hopefully contribute to a future sustainable drinking water supply that also is resilient to future climate changes.

What have we done

- Field investigations (SkyTEM, seismics (LIAG), drillings)
- Additional field investigations in area of specific interest (TEM40, investigation drilling)
- Workshops on groundwater potential, water quality
- Field investigations in area of specific interest with the new developed Tow-TEM method
- Two investigation drillings (done by Water Utility Company, Din Forsyning) in area of specific interest (verification of ground water aquifer in quaternary buried valley system)
- Pumping tests and water analysis
- Stakeholder involvement of local authorities and land owners
- Preliminary geological vulnerability assessments in specific area of interest
- Extension of 3D geological model and hydrological model (in progress)

What is still to be done

- Additional geophysical field data (Tow-TEM) in the start of 2019
- Further stakeholder involvement of local authorities and land owners
- Extended 3D geological model with Topsoil details (0-50 m ´s) – focus on buried valley aquifer system and protective clay thicknesses
- Extended hydrological model and different scenarios (extraction scenarios, climate scenarios)
- Future planning
- ...

QUALITY INDICATOR

Baseline	Problems with the present drinking water supply in Varde town (problems with nitrate and pesticides)
Target	A future sustainable drinking water supply to the consumers that also is resilient to future climate changes
Target time	2020-2022
Considerations	...

PARTNERS AND STAKEHOLDERS

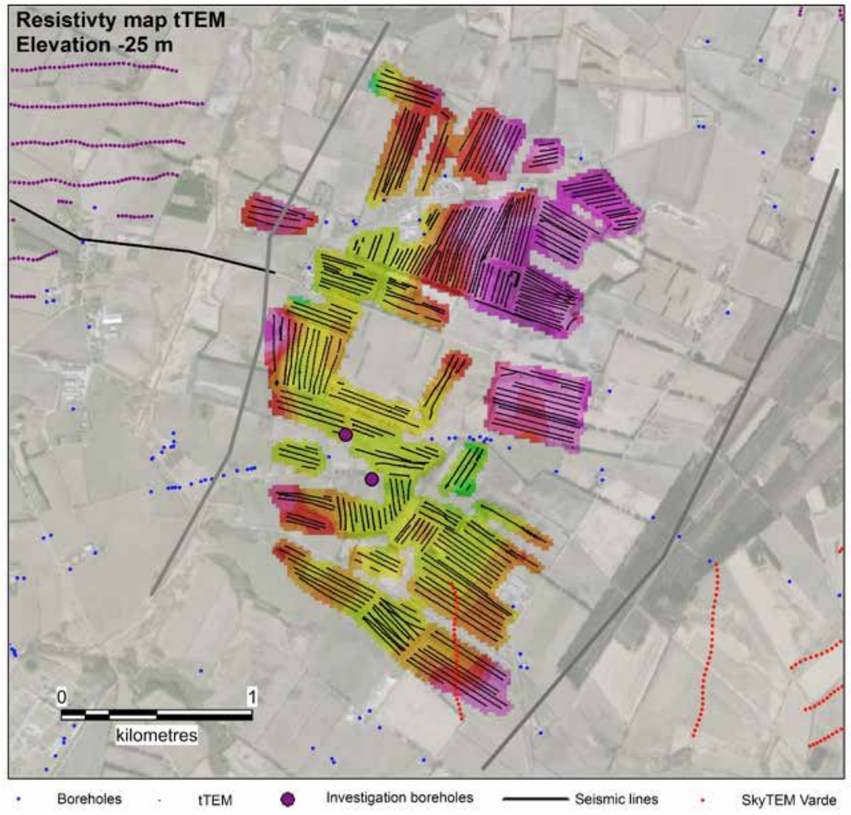
Topsoil partners:
GEUS: 3D geology and hydrological modelling - Anders Juhl Kallesøe
External partners:
Aarhus University: Tow-tem data - Jesper Pedersen
LIAG: Seismic data - Helga Wiederhold
Stakeholders:
DIN Forsyning (Water utility)
Land owners / farmers
Varde municipality (local authority)

PRELIMINARY RESULTS

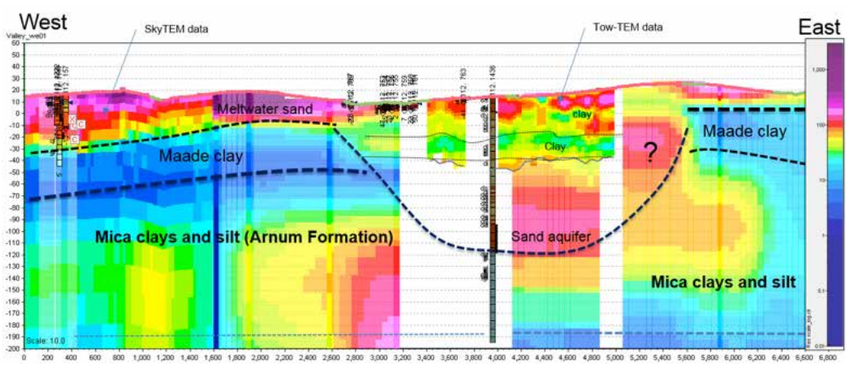
For securing a clean sustainable drinking water supply (groundwater without pesticides and high contents of nitrate) to the inhabitants in Varde town an intense mapping of the subsurface in areas around Varde started in the years 2015 -2016. A regional geophysical SkyTEM survey to map the subsurface in the northern part of the Varde area was completed just before the beginning of the Topsoil project. The results of the SkyTEM survey was the initial data starting point in this Topsoil pilot in order to face the challenges of finding a sustainable and clean drinking water source and how to make detailed vulnerability studies in complicated geological settings.

In 2016 a preliminary 3D geological model and hydrological model have been established to better understand the hydrogeological conditions of the area. From 2016 to 2018 additional field data have been collected to improve the knowledge. In a specific area of interest the new developed Tow-TEM (tTEM) method has been tested with promising results. Also seismic data has acquired by LIAG, a small TEM40 survey was done and 3 investigation drillings were established.

The new data has revealed a quaternary buried valley towards northwest of Varde town. The tow-TEM gives valuable information on the valley infill that is now being analysed in the detail regarding groundwater vulnerability in the area.
Additional geophysical data will be collected in order to improve knowledge of the valley systems and feed into an extended 3D geological model and hydrological model with the purpose to test relevant scenarios (environmental impact, effects of change in ground water extraction, climate change...).



2D resistivity map (Elevation -25 m) for the tTEM survey. The interpreted sides and orientation of the buried valley system are shown with grey lines.



Cross section in area of interest. Sketch of buried valley system cutting through Miocene clays deposit. TTEM 3D resistivity grids is shown between 3000 to 5000 meters giving information om the upper parts of the valley infill sediments.

Integrated water management in Odense City for improved risk assessment

CHALLENGES

- **Flooding**
- **Saltwater intrusion**
- **Groundwater buffer**
- Soil conditions
- **Break down capacity**

Background and objective

Odense City is threatened by inundation from increasing groundwater levels and flooding events from both the river, the fjord and flash floods caused by extreme precipitation. An optimal management of urban water cycle in a future more extreme climate requires an integrated approach that combines the individual components: geology, hydrology, urban and climate data.

The overall objective of the project is to create a tool which can be used for management of water flow in urban areas in climate change conditions and access the risk for contaminated point sources. It is believed that an integrated hydrological modeling approach is the most efficient way to quantify the impacts of both climatic changes, adaptation measures and changes in urbanization. All those factors affects the urban hydrological cycle, including groundwater levels, groundwater and surface water flow paths and resulting in migration of pollutant from the point source contamination.

What have we done

- Geological model
- Hydrological model
- Particle transport model

What is still to be done

- Chemical transport model
- Hydrological model in a future climate

QUALITY INDICATOR

Baseline	The baseline for the project is the number of point sources that today pose a threat to the waterworks, and therefore must be remediated. Another baseline is the number of houses threatened by inundation from increasing groundwater levels and flooding events from both the river, the fjord and flash floods caused by extreme precipitation.
Target	We will be able to reduce the number of point sources that has to be remediated with 20%, and we expect to reduce the number of houses with groundwater problems by 20 %.
Target time	2021
Considerations	The abstraction strategy of the waterworks and the future climate change are very important for the model results

PARTNERS AND STAKEHOLDERS

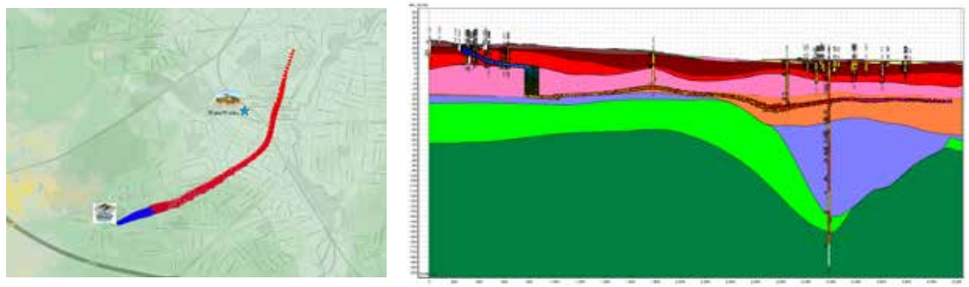
Topsoil partners:
Southern Denmark Region - Jørgen Christensen - Agnieszka Bentzen
External partners:
GEUS: Modelling - Torben Sonnenborg
Aarhus University: Geophysics - Jesper Pedersen
Stakeholders:
Odense Municipality
Vandcenter Syd (Water company)

PRELIMINARY RESULTS

Based on a wide range of data such as drillings, geophysics and fine gravel analyzes we have developed a 3D geological model. Subsequently, a detailed hydrological model has been constructed for the area, which has been tested against a historical period representing significant changes in groundwater abstraction and climate. Based on the hydrological model, we have conducted particle path simulations. The particle path simulations are made in the Particle Tracking module in MIKE SHE, which calculates the 3-dimensional flow path for a desired number of particles emitted from selected cells within the model range. From each source 500 particles have been released on the day the pollution has started and no particles have been released after that day. The simulations are made with neutral particles that neither degrade nor absorb to the sediments.

The particle path simulations have been carried out on two point sources in the area. The figure below shows one of the simulations preformed. As shown in the figure, the particles from the point source never reach the waterworks. This situation is not stationary but can be changed if the waterworks amend their abstraction strategy or due to climate changes in the future.

Therefore it is important to use an integrated approach that combines the individual components: geology, hydrology, abstractions data, urban and climate data, to carry out a risk assessment that reaches out in to the future.



The figure shows particle path simulation both horizontally and vertically

GE1

Investigation of the geophysical, hydrochemical and hydraulic characteristics of the subsurface in a moraine area and adjacent marshlands as a basis for geological and hydrological modelling

CHALLENGES
- **Flooding**
- **Saltwater intrusion**
- **Groundwater buffer**
- Soil conditions
- Break down capacity

Background and objective

The pilot area is characterized by the transition from a moraine area with sandy soils to the marshlands of the rivers Stör and Elbe. Groundwater recharge takes place in the moraine area, while in the drained marsh areas saline groundwater with shallow freshwater lenses occurs. Groundwater modelling based on a geological model will allow a better prediction of future changes of groundwater tables, freshwater-saltwater distribution and the demand for drainage under the impact of climate change and sea-level rise.

Additionally, the sinkhole area in the village of Münsterdorf is investigated with geophysical methods to understand solution processes of the near surface limestones to enable a better delineation of the sinkhole risk area.

What have we done

- Reflection seismic survey
- Resistivity measurements
- NMR test measurements
- Evaluation of electrical soundings (archive data)
- Evaluation of chemical groundwater data
- Evaluation of HEM data /aero geophysics
- Geological model

What is still to be done

- Groundwater modelling

Streamer with geophones

A smaller seismic source called "ELVIS"

QUALITY INDICATOR

Baseline	The influence of expected heavy rainfall and increasing ground water recharge on surface and ground water, salt water intrusion and the future demand for drainage will be quantified
Target	Provide soil and drainage associations with information of the future demand for pumping including the need for new technical installations
Target time	2020
Considerations	-

PARTNERS AND STAKEHOLDERS

Topsoil partners:
Central Denmark Region
LIAG Hannover
LBEG Hannover
External partners:
CAU Kiel
TU Berlin
BGR Hannover
Stakeholders:
Public authorities, Consulting agencies, Water companies
Municipalities, Landowners

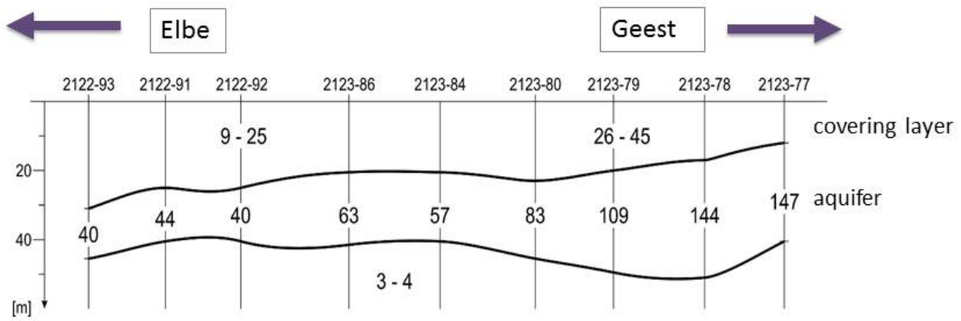
PRELIMINARY RESULTS

To understand the processes of the surface-near water circle, the spatial distribution as well as the petrographic and hydraulic properties of the aquifers and covering layers have been investigated in the area of the geological and hydrological models. In this context a combination of different hydrogeological and geophysical methods have been applied.

The basis of the geological structure model was the evaluation of about 4.900 well descriptions. Additionally data from geophysical surveys like electrical soundings or aero geophysics were used to build up the geological 3D-model.

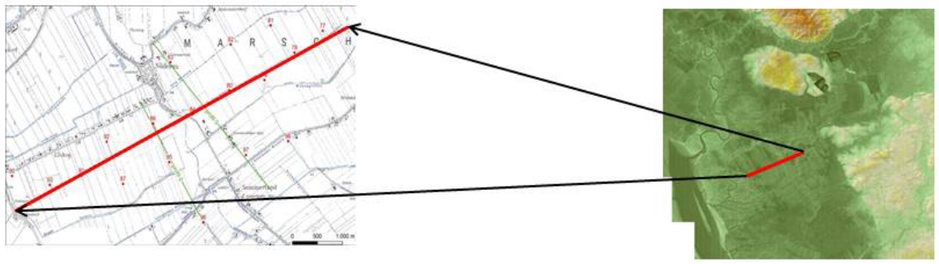
Since in the marsh area only few data of ground water chemistry exist, results from a HEM survey and geoelectrical soundings were used to map the spatial distribution of fresh and salt water in the marsh area.

Resistivity depth distribution along a profile of geoelectrical soundings

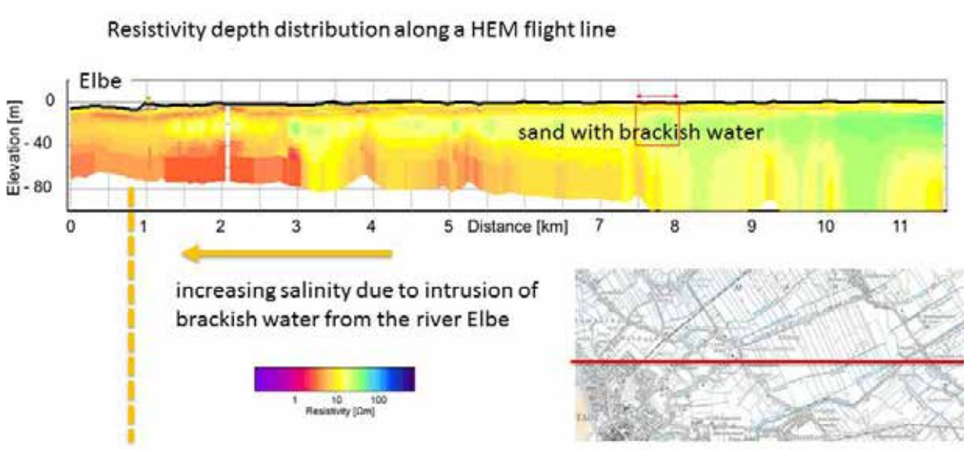


resitivity depth profile, specific electrical resistivities in Ωm

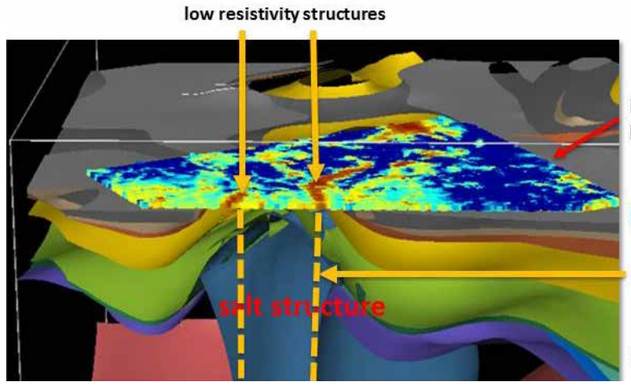
increasing electrical resistivity – less influence of brackish water from the Elbe



Resistivity depth distribution along a HEM flight line



Geological 3-D-Model combined with HEM data



HEM resistivity map 30 – 40 m below ground

Reason of low resitivities:

- edge of the salt structure ➔ related to low resitivities
- updoming clay

Streamer with geophones

GE2

Development of climate change effected saltwater intrusion in the Elbe-Weser-region

CHALLENGES
- Flooding
- **Saltwater intrusion**
- **Groundwater buffer**
- **Soil conditions**
- Break down capacity

Background and objective

Progressive salinization of coastal aquifer systems respectively an upward shift of the salt-/freshwater interface (SFI) could limit the water supply and the agricultural use of coastal areas. To quantify the effect of the climate change and the related changed rainfall distribution, irrigation and drainage in the Elbe-Weser region a groundwater flow model will be developed. A detailed large-scale geological model and the current state of salinization serve as a basis.

The aim is to model the shift of the salt-/freshwater interface (SFI) within different climate scenarios and to quantify the effect of drainage, irrigation and additionally groundwater storage in the geest areas to the SFI.

What have we done

- Data acquisition
- Direct push drillings and groundwater sampling
- Drainage water sampling
- Sediment sampling
- Modeling of the SFI (current state)
- Large-scale geological model

What is still to be done

- Groundwater model
- Simulating the impact of different climate change scenarios on groundwater recharge and the SFI
- Modelling and evaluation of freshwater enrichment in geest areas

QUALITY INDICATOR

Baseline	Vertical resistivity sections (HEM-data) and groundwater quality data have been used used to model the SFI current state.
Target	Reduce 20 % of the saltwater effected area in the coastal aquifer or reduce the worsening of the situation due to climate change
Target time	Near future
Considerations	-

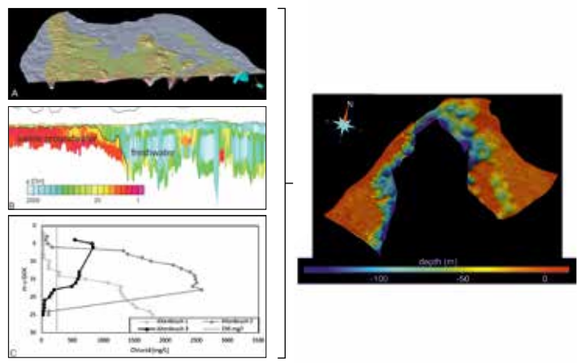
PARTNERS AND STAKEHOLDERS

Topsoil partners:
LBEG & LIAG
Stakeholders:
Farmers and land owners
Local water supplier
Drainage association
BGR

PRELIMINARY RESULTS

The large scale geological model (Fig. 1A) has been conceived as a base layer model with 15 geological units. Input data were bore logs (Lower Saxony (Germany) borehole database), geological sections and the geological map 1: 50 000 as well as the HEM (helicopter electromagnetic) data of the D-AERO project (BGR, 2013). This structural model will be used as input data for the planned groundwater flow model.

Fig. 1D shows the current state of the salt-/freshwater interface in the project area. In the lower marshland with heights of -3 – 1 m a.s.l. the SFI is close to the surface. Towards the moraine ridges with heights up to 70 m a.s.l. and a groundwater level about 10 m a.s.l. the depth of the SFI increases. The interface has been modeled with the help of the HEM vertical resistivity sections (Fig. 1B), information about the chloride content in groundwater and borehole geophysics. Results of our direct push drillings (Fig. 1C) were used to validate the modeled SFI. A comparison between the HEM-modeled SFI and the direct push results shows good correlations.



With the knowledge about the geology (A), resistivity distribution in depth (B) and chloride content in groundwater samples (C) the current state of the salt-/freshwater interface (D) has been modeled.

Bremen Dam: effects of a dam on the surrounding groundwater

CHALLENGES
- **Flooding**
- **Saltwater intrusion**
- Groundwater buffer
- Soil conditions
- Break down capacity

Background and objective

In Bremen the Weser river is backed-up in order to the production of electric power and to improve shipping traffic. To control the high tidal range, the Weser dam was built in recent years. Due to the ailing condition of the weir, it came to the breakthrough in march 1981. To avoid further catastrophes a new dam was build 180 m downstream in the 90th. However, this had noticeable consequences to the groundwater regime and the communication between riverbed and aquifer on small and large scales. Field investigations from geoelectric logs to geochemical measurements like CHC from contaminated sites or chloride measurements can help us to detect the changing groundwater quality and the shifting of the dynamical freshwater-saltwater interface. On large scales a distinguished knowledge from prediction models as high-resolution groundwater- and transport modelling is needed. Therefore, different scenarios are explored: what impact does the climate change have on the interaction between aquifer and river? What does the rising sea level and changes in groundwater recharge mean for future groundwater use?

What have we done

- New data sets have been collected: boreholes, analytical data (Chloride)
- Progress in the refinement of the 3D-structural model
- Start with a parameterized (hydraulic conductivity) conceptual groundwater model
- Test the tidal influence on possible saltwater-intrusion

What is still to be done

The refinement of the 3D-model is still running but for a coherent model, we need more information from the construction phase of the dam as under water sheet pillings (bulkheads) and their transmissivity. Further geochemical indicators like chloride measurements will be done soon and will help us to learn more about the interaction between riverbed and aquifer and saltwater-intrusion from the upper river into the aquifer

Several data campaigns were started from June 2016 up to now.

QUALITY INDICATOR

Baseline	With a hydraulic model the prediction of the ground water flow and the dynamical saltwater-freshwater interface will be possible (in context to climate change)
Target	20 % less influenced groundwater by saltwater intrusion (Chloride)
Target time	2100
Considerations	Different scenarios by considering: e.g. sea level rising, decreasing recharge, salt input, tidal effect

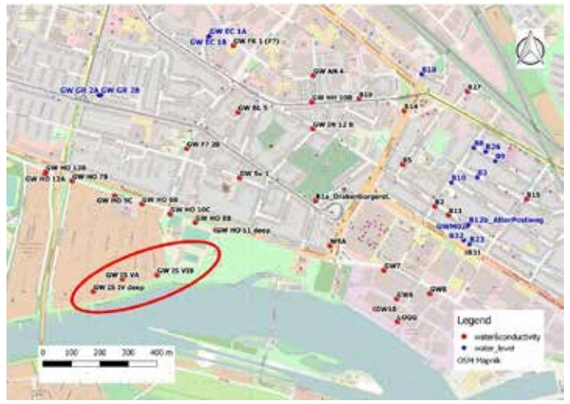
PARTNERS AND STAKEHOLDERS

Topsoil partners:
Geological Survey of Bremen - Investigations, modelling - Björn Panteleit, Joachim Blankenburg, Katherina Seiter (kseiter@gdfb.de)
External partners:
Dr. Pirwitz: Consultancy
Stakeholders:
B. Leferink: Senator for Environment etc.

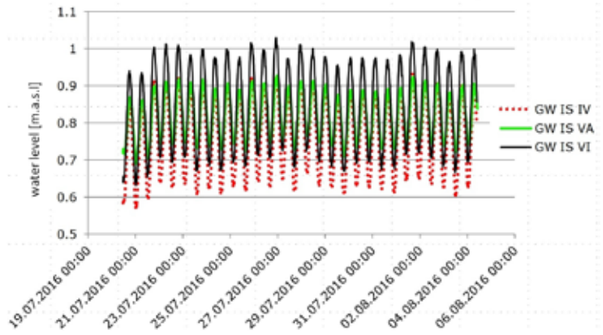
PRELIMINARY RESULTS

Together with our partners and stakeholders several new data sets have been collected, thus a wide range of geological drillings could be added to refine the conceptual 3D- model from the groundwater body. In a first attempt the tidal influence with a homogenous four layer isotropic voxel model (parameter: hydraulic conductivity) has been tested, tidal effect and damp could be simulated well. Additional geoelectric resistivity logs were used to detect the tide-depending fresh-saltwater interface and define a possible saltwater intrusion with promising results. Furthermore, groundwater field data from hazardous substances in the investigation area helped us to reconstruct the groundwater flow and to check groundwater quality changes.

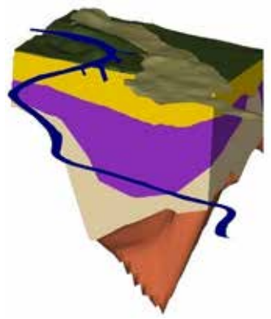
Geoelectric campaign at the Weser-Strand (University of Bremen)

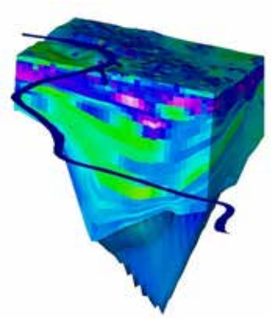


Beside standard parameters like temperature and groundwater level measurements, electric conductivity data were collected.

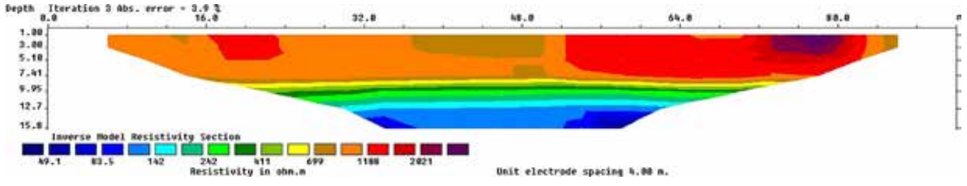


Periodical water level fluctuations near the river bank (red elipse in the map above)





3D-model of the project area. Left: structure model, first attempt to be refined, right: parameterized with hydraulic conductivity)



First results from the geoelectric campaign at the Weser-Strand (university of bremen). The colour bar show the resisitivity.

AquaModul

CHALLENGES

- Flooding
- Saltwater intrusion
- **Groundwater buffer**
- Soil conditions
- Break down capacity

Background and objective

Due to sandy soils and a strong negative climatic waterbalance during the vegetation period the county of Uelzen has become the center of Germany's largest agricultural irrigation area. Mainly groundwater is used. The limiting factors to the necessary additional groundwater extraction due to climate change are the WFD as well as Nature 2000 requirements of preserving and improving protected groundwater dependant ecosystems.

During the last decade the hydrological effects of the summary of the wells have been investigated with the help of iterative modelling. Yet a practicable monitoring system and interpretation methods have been lacking and shall be developed and tested now. A special focus lies on the interdependence of aquifers and small rivers baseflow. Special challenges are further the size of the involved groundwaterbodies (ca.1470 km²) and even more the specific discontinuous groundwater extractions only during drought situations within the vegetation period from ca. 1200 irrigation wells. The searched for hierarchic monitoring system is planned to become the basis for the future management of extractions and measures including artificial recharge.

What have we done

- Hydrogeological numerical flow model calibrated with reference date measurement of 270 wells.
- Installation and first testing of the three acoustic Doppler elements (ADCP-Technlogy) for small river flow measuring. Problems faced: changing flow patterns (including swirls) of creek depending on discharge intensity. Creek fell dry due to record drought in 2018. Sensor became covered with algae due to installation at a site without shade. Drifting wood and sand during spring impaired the ADCP-sensors.
- Installation of 3 times 2 monitoring wells (one in the upper and one in the lower aquifer) near 3 ADCP for identifying locally interdependencies between aquifers and small rivers' baseflows
- Initial interpretation of data. Problems faced: distinguishing of baseflow effects from beginning rainfall and/or stopping irrigation was yet difficult.
- Discussion of to be calculated scenarios with stakeholders (authorities).

What is still to be done

- Continue testing of the flow measuring equipment (ADCP); functioniog of measurement during flood events could not be tested yet flood measurement wanted
- Collect more data from upper and lower aquifers' watertables and corresponding small river flows
- Improve data interpretation and do instationairy calibration of model
- Define areas corresponding to the monitoring sites or even areas for transfer of results
- Identify where necessary additional flow measuring sites in the groundwaterbody are needed
- Modelling of different scenarios
- Develop proposals for stakeholders for decision support of extraction management and of groundwater quantity management as a whole

QUALITY INDICATOR

Baseline	Neither a quantity nor a quality indicator are applicable as AquaModul's focus lies on introducing, testing and interpreting of innovative measuring technology in natural watercourses. With the help of the monitoring at a later point of time, the extraction of groundwater can hopefully be increased in defined siuations.
Target	-
Target time	-
Considerations	-

PARTNERS AND STAKEHOLDERS

Topsoil partners:
Dachverband Feldberegnung Uelzen: Modelling and monitoring - Jörg Martens
Landwirtschaftskammer Niedersachsen
Stakeholders, communication - Elisabeth Schulz
Stakeholders:
Landesamt für Bergbau: Energie und Geologie (LBEG)
Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz (NLWKN),
Landkreis Uelzen (County of Uelzen)

PRELIMINARY RESULTS

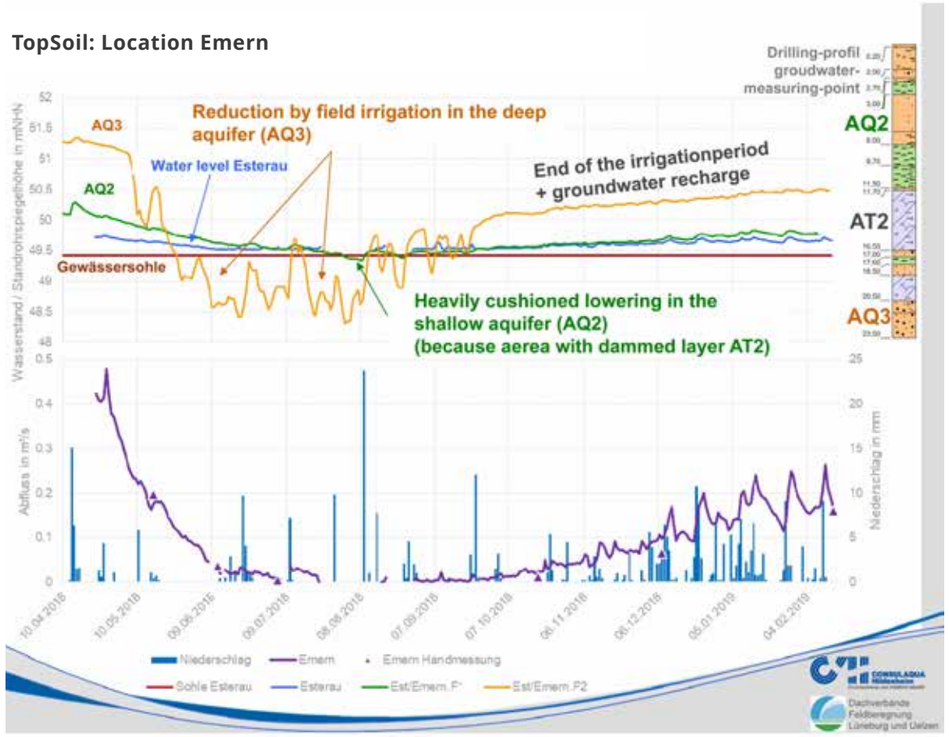
The installation of the ADCP-Sensors (see picture) in three small watercources for measuring the waterflow (= "Abflussmessung", see schematic model) in combination with parallel installation of each time 2-aquifer measuring wells led to first results about the interdependence of groundwater extraction ("Wasserentnahme + Feldberegnung"), baseflow, first and second aquifer (= 1. und 2. "Grundwasserleiter") and aquitard (= "Grundwasserhemmer") in all three pilot sites.

For example see pilot small river "Esterau". From the „independant" course of the yellow line can be concluded that there is no signifikant hydrological connection between the second aquifer with neither the first aquifer nor the run off in the Esterau. Thus groundwater extractions from the lower aquifer should not or only very retarded effect the small river. However – focussing on the courses of green and blue line - the upper aquifer and the river communicate well and therefore the upper aquifer should be excluded from groundwater pumping.

ADCP for flow measuring

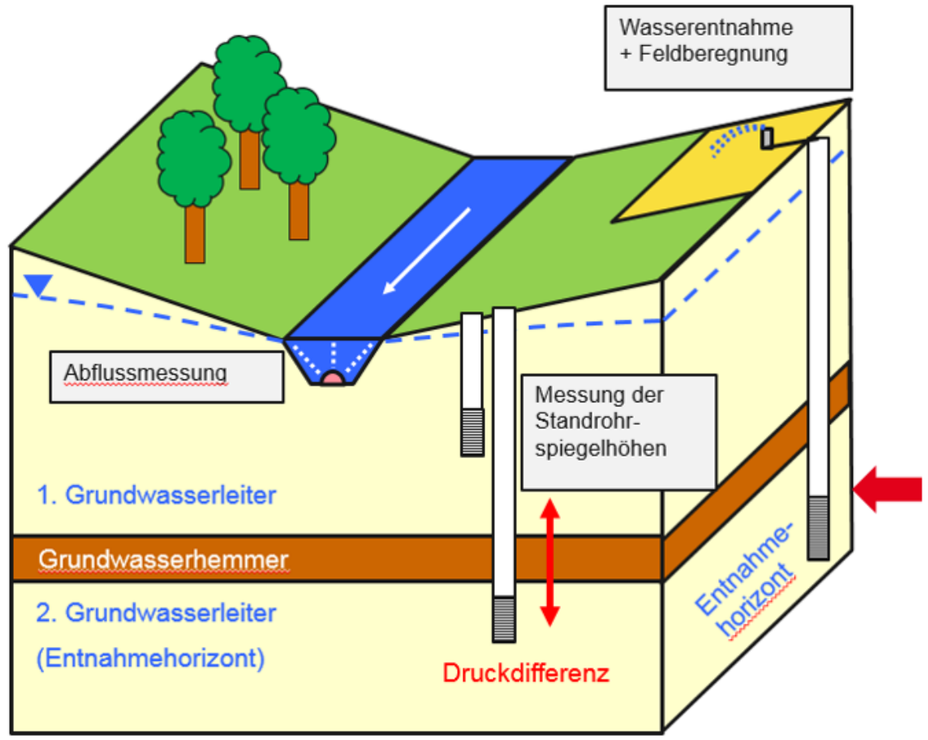
Control and energy supply station for ADCP

TopSoil: Location Emern



Yellow line = gauge level of lower aquifer which is aquifer of groundwater extraction => influenced by different quantities of irrigation
Green line = gauge level of upper aquifer => no influence of extractions due to protection from aquitard
Brown line = bottom of small river Esterau
Blue line = water level of Esterau
Violett line = Run off of Esterau (m³/s)
Blue columns = rainfall (mm)

Scheme of parallel monitoring of stream flow, upper and lower aquifer at one location



GE5

Enabling farmers to better protect the groundwater from nitrate and veterinary pharmaceuticals

CHALLENGES

- Flooding
- Saltwater intrusion
- Groundwater buffer
- **Soil conditions**
- **Break down capacity**

Background and objective

This pilot in the western part of lower Saxony aims to strengthen the precautionary drinking water protection at farm level. Large parts of the provision area of the OOWV are characterized by intensive agricultural land use combined with little buffering soil conditions, i.e. with vulnerable underlying groundwater bodies. This pressure feeds concerns that pollutants (e.g. nitrates) are on their way to groundwater layers and constantly threatening drinking water production: if they reach the water procurement areas (i.e. the deeper groundwater layers), it will be very difficult for water suppliers to remove them again. BGR and OOWV thus work on a tool which helps farmers to better assess the vulnerability of their soil, and set priorities for specific, groundwater protecting management.

What have we done

The OOWV established a cooperation with four farmers to advance groundwater protection. The farmers participate in the project by implementing measures on all areas of their farms in the drinking water catchment area. For this purpose, digital and sub-area-specific soil maps were made at the beginning of the cooperation. These maps can be used to adapt fertilisation and management to specific sub-areas, taking into account the soil properties and groundwater hazards of the site. The participating farmers receive advice on fertilisation planning from the Chamber of Agriculture. In addition, there is a regular exchange between the farmers, the OOWV and the Chamber of Agriculture. The BGR analyses soil water and seepage water quality on agricultural land. For this purpose, geophysical (electromagnetic and radiometric methods) and soil measurements are carried out. Active and passive infiltration experiments are performed in order to investigate and understand the process of infiltration and material displacement.

What is still to be done

In order to be able to make reliable statements about the effects of the tested groundwater protection measures on the sites, further measurements must be carried out. The very rainy year 2017 and the extremely dry summer of 2018 mean that the measured values of nitrate in soil are not easily transferable. The cooperation with the farmers will be continued beyond project duration of Topsoil. Consideration is also being given to taking over the farm-level approach to other areas of cooperation. The BGR will further evaluate the data and is preparing to publish the results. By combination of radiometry and electrical conductivity measurements on the field scale with the small scale heterogeneity investigation of flow processes BGR tries to detect correlations between flow processes and geophysical parameters on bigger scales. If successful, these correlations shall be used for recommendations with regard to spatially variable manure application to achieve groundwater pollution reduction.

QUALITY INDICATOR

Baseline	Digital soil maps improve the ability to implement precautionary drinking water protection at farm level. Research on soil and seepage water lead to a better understanding of the process of infiltration.
Target	20 % nitrate reduction in the soil measured in autumn by groundwater protection measures and soil specific farming
Target time	2022
Considerations	Weather conditions have an impact on the measured nitrate values

PARTNERS AND STAKEHOLDERS

Topsoil partners:
OOWV
BGR
Stakeholders:
Chamber of Agriculture
Farmers

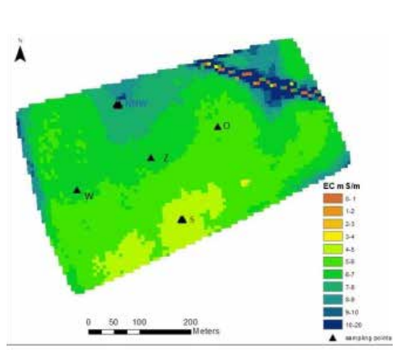
PRELIMINARY RESULTS

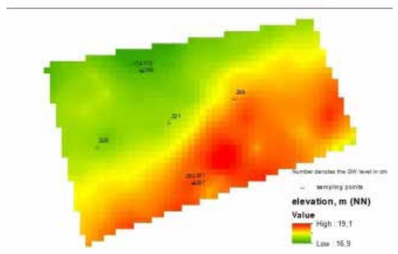
Plot-scale study to water flow heterogeneity and the relevance of preferential flow paths for groundwater contamination:
The multitracer irrigation experiments combined with electrical resistivity tomography were carried out to assess the relevance of preferential flow for groundwater contamination on a selected sandy agricultural field in Cloppenburg region.

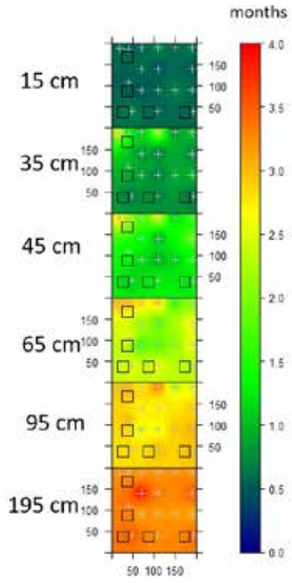
The tracer breakthrough in percolating water collected at 50 cm depth by suction plates and the spatial distribution of the tracer in soil after irrigation experiment indicate the existence of the continuous preferential flow paths and the regions with no-flow. The water redistribution must have taken place under the plough pan to explain the observed variability in data. The plough pan allows water penetration only through the few narrow paths and transports the part of water laterally to the next place of penetration. The electrical resistivity data bear a general resemblance to the tracer distribution but not in details because of limited resolution. The water residence time increased steadily with soil depth from 0,4-0,8 months (13-22 days) at 15 cm to 3-4 months (94-119 days) at 195 cm. Most variability in water residence time 1-3 months (25-86 days) was observed at 45 cm depth. Overall, very fast transport of water on a selected site seems to be responsible for the groundwater pollution here.

Field-scale study for identifying the heterogeneity in soil- and groundwater properties using geophysical tools:
The geophysical survey (EM and Radiometry) in combination with soil- and groundwater sampling was conducted at three agricultural field. The preliminary results show that for a field with a high-contrast soil texture the electrical conductivity data explains the big part of variability in clay content, whereas for the rather homogeneous sites with sandy soil the variability in soil organic matter content or in chemical composition of the top-most groundwater could not be explained by geophysical measures.

One of three study fields with high groundwater table exhibited a great variability in nitrate concentration in the top-most groundwater, despite the uniform agricultural practice. One part of the field have nitrate concentrations higher than 50 mg/l, while at the other part of the field the nitrate concentrations in top-most groundwater are close to zero. Further investigations are required to understand such a localized activity of the denitrification processes.







NL1A

Fresh water Drentse Aa

CHALLENGES

- Flooding
- **Saltwater intrusion**
- **Groundwater buffer**
- **Soil conditions**
- Break down capacity

Background and objective

Climate change will affect Nature and Agriculture. The objective of this pilot is to find measures to deal mitigate the increased water shortage due to climate change in the catchment of the Drentse Aa (measures to deal with increased flood risk are already being implemented in this catchment).

A groundwater model is used to study the effect of increased drought due to climate change and to develop measures to reduce the increasing drought risks for nature and agriculture.

Stakeholders are involved in the actualisation of the model and during the evaluation of measures.

What have we done

- An existing ground water model of the pilot area has been actualized.
- With the model the effects on seepage and groundwater levels have been calculated for:
  - The autonomous developments.
  - The drought due to climate change on water dependent nature in 2050.
  - Potential measures to mitigate the effects of climate change on nature.
  - A buffer zone around nature areas for irrigation from ground water.

What is still to be done

- Make a final report
- Discuss the potential measures with decision maker
- Implement the measures

QUALITY INDICATOR

Baseline	Surface of water depended nature (ha) in the Drentse Aa catchment. Surface of agricultural area (ha) in the Drentse Aa catchment.
Target	In 20% of water depended nature the effect of climate change can be mitigated. In 20% of agricultural area irrigation from groundwater can be allowed.
Target time	Implementation of measures is expected after 2019
Considerations	Costs of measures are not yet determined. When the costs are too high some measures might not be implemented

PARTNERS AND STAKEHOLDERS

Topsoil partners:
Waterschap Hunze en Aa's: Water authority - Jan den Besten
Partners:
Province Drenthe: Strategic policy - Rinke van Veen
External partners:
Querner Consult: Groundwater model
Stakeholders:
Farmers and landowners
Nature organization
Drinking water company

PRELIMINARY RESULTS

A hydrogeological model of the uppermost 50-100 m of the subsurface with a top-layer model has been actualized. With the model the effects of increased drought due to climate change on ground water levels and seepage have been determined for water depended nature areas. With the model the most promising mitigation measures have been evaluated for nature and agriculture and have been presented and discussed with stakeholders.

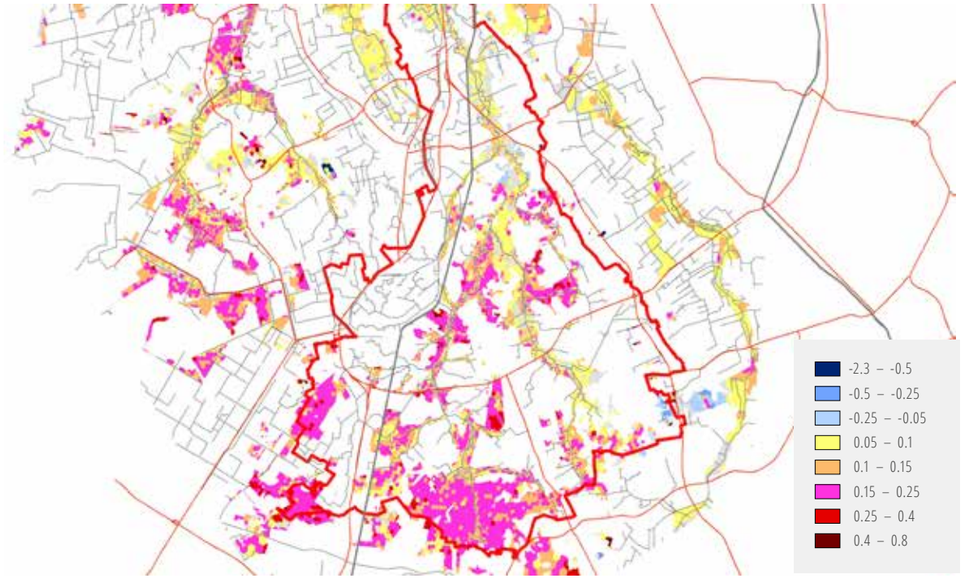
In this way we developed a management plan for climate adaptation to increased drought that contains the following measures:

- Change coniferous forest into deciduous forest or into heather.
- Raise the river beds.
- Raise the level of new tube drains (from 1,1 m to 0,8 m –surface level) and put drains every 5 m instead of every 10 m.
- Use groundwater for irrigation in areas that are at more than 500 m distance of nature areas with a maximum extraction of 50 mm per year.

The selected measures will be discussed with the policy makers within the province, the Regional Water Authority and the nature organisation.

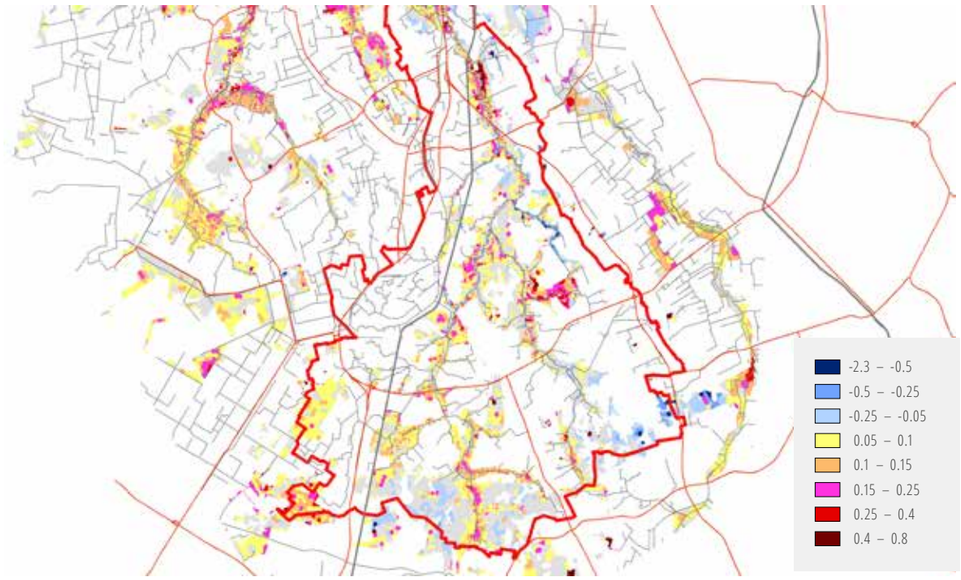
The implementation of the measures will depend on the outcome of these discussions. Also the related costs will influence the implementation.

Most of the measures are expected to be implemented after the end date of Topsoil. However the Regional Water Authority is already studying how the river beds can be raised and the Province of Drenthe is studying how the depth for drain tubes can be reduced.



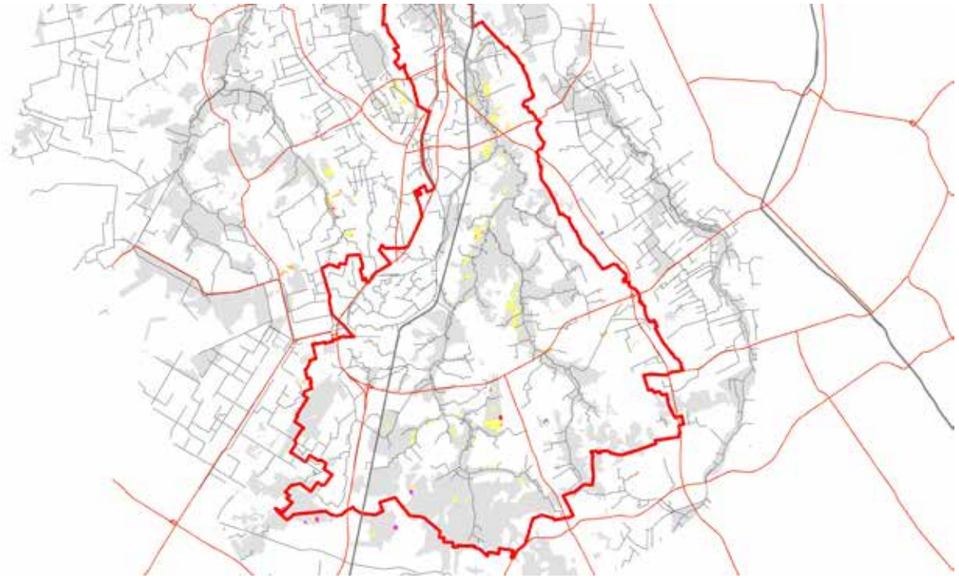
Effect of climate change on water depended nature in 2050
Ground water level change at the end of a dry summer
(Climate scenario KNMI 2050Wh)

Changes in ground-water level (cm)



Effect of mittigating measures in groundwater depended nature in 2050
Mitigting measures: raising river beds, raising tube drain levels and changing coniferouous forests into deciduous forests

Changes in ground-water level (cm)



Zones where can be irrigated from groundwater with 50 mm/year without effecting water depended nature areas when using a buffer zone of 500 m around nature areas. (grey dotted ares)

NL1B

Water quality Drentsche Aa and Hunze

CHALLENGES

- Flooding
- Saltwater intrusion
- Groundwater buffer
- **Soil conditions**
- **Break down capacity**

Background and objective

Climate change will affect the impact of agriculture activities on water quality of surface water. The aim of the project is to get better grip on the increased leaching of nutrients and pesticides due to climate change. And also to determine measures together with farmers in the area best to be taken. A hydrological model and a quality model has been built to determine the high risk areas on leaching and run off of nutrients and pesticides for the catchments of the two brooks Drentsche Aa and Hunze.

What have we done

- A hydrological model is built for the two brooks using open sources (SWAP model)
- This model is used as input for building the quality model SWAT
- Data on land use, manuring and intensive data on soil types are collected for the SWAT model
- Risk maps are produced on determining the areas where run off and leaching will take place most likely
- A Travel time research is carried out in the brook Drentsche Aa. In this research time is calculated that is needed to travel from one point in the brook to the intake point for the drinking water company.

What is still to be done

- Analyse the outcome of the SWAT modelling
- The reality check with the stakeholders in both catchments
- Determine the top 5 measures to be taken by farmers
- Run through the model three of the measures programs
- Run through the model a climate scenario that is most important for having effect on surface water quality in relation to agricultural management

Field measurements

QUALITY INDICATOR

Baseline	• Surface waterquality of the Drentsche Aa considering total- fosforus total and pesticides • Surface water quality of the Hunze considering total-fosforus and total-nitrogen
Target	• Drentsche Aa: preventing P status to deteriorate (stand still); for pesticides the aim is 50 % less exceedings of the Water Framework Directive guideline drinking water in 2018, 95 % less exceedings in 2023. • Hunze: preventing P and N status to deteriorate (aim standstill);
Target time	• Implementation of measures considering nutrients expected after 2019 • For pesticides the top soil results will be used for a project on field leaching and run off which will start in 2019, in order to determine the best management practices to prevent pesticides coming into the brook
Considerations	Awareness and behavioral changes by the stakeholders is an important result as well.

PARTNERS AND STAKEHOLDERS

Topsoil partners:
Waterschap Hunze en Aa's: Water authority - Marian van Dongen
Partners:
Province Drenthe: Strategic policy - Rinke van Veen
External partners:
Watercompany Groningen: Drinking water policy
Consortium RPS/AcaCIA/Delphy: Modelling
Stakeholders:
Individual farmers
Farmers organization

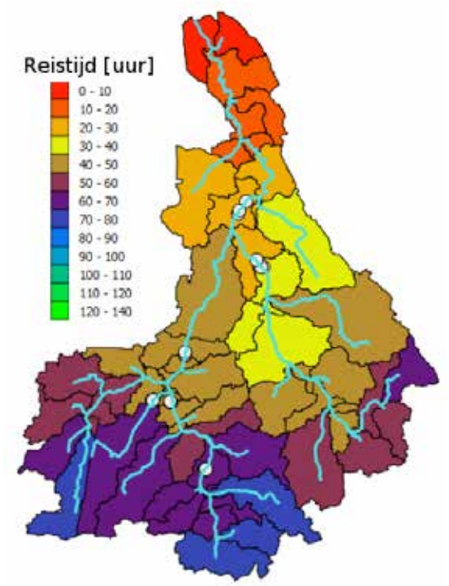
PRELIMINARY RESULTS

The hydrological Model SWAP has been build and runs were made with more accurate soil data, delivered by Wageningen University. First versions of risk maps for leaching and run off have been produced by this model. The SWAP model is used as a base for the quality model SWAT in which more data are used on manuring, land use and processes on nitrogen and phosphorus in the soil. A report on both models is expected in November 2018.

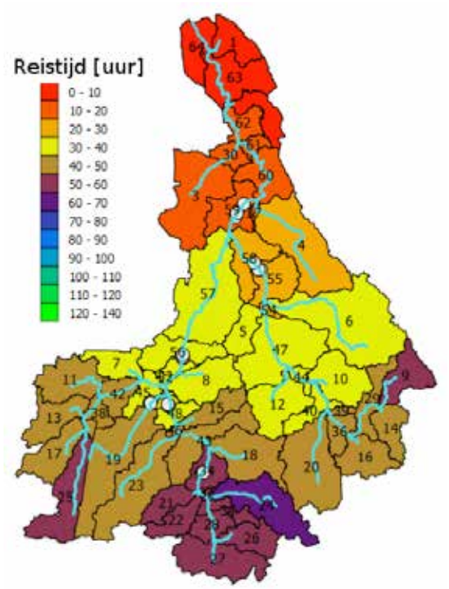
On 28 September 2017 and 15 May 2018 field measurements have been done with a tracer to determine the dispersion coefficient in the Drentsche Aa. A report on the time travel experiment is expected in November 2018. Time travel maps on normal and high discharge conditions were produced. (see pictures below). Through this experiment information on flow, transport, and mixing processes in surface water is obtained. It provides the drinking water company knowledge about the time that they have to react before water arrives at the intake point at the time a calamity takes place in the catchment.

On 9 March 2018 on the International Topsoil meeting the pilot water quality Drentsche Aa & Hunze has been presented as a case to discuss the use of the model SWAT for making risk maps on leaching and run off of nutrients and pesticides.

The three most likely to be taken measures by farmers will be run through the SWAT model to calculate the effect on water quality. The implementation of the measures will be taken up in a new project after Top soil has ended.



Time Travel research in the brook Drentsche Aa. Cumulative travel time under normal discharge conditions (1 m³/sec)



Cumulative travel time under high discharge conditions (7 m³/sec)

NL2

Sustainable Dwarsdiep catchment

CHALLENGES
- Flooding
- Saltwater intrusion
- Groundwater buffer
- **Soil conditions**
- **Break down capacity**

Background and objective

A lot of activities will take place in the Dwarsdiep catchment the coming years. The activities are in terms of creating water storage, creek restauration and creating nature. Additional to these measures the Topsoil project 'Sustainable Dwarsdiep Catchment' focuses on the farmer parcels on the flanks of the catchment. Surface water supply during dry periods is on the flanks not possible. The expectation is therefore that this area will be more drought sensitive in future. The goal of the Topsoil project is to find a set of measures on parcel level which improves agriculture circumstances but meets the goals of the regional water authority for quantity and quality as well, now and in future. The strategy is to emphasize the mutual benefit and the relationship between parcel and catchment level.

What have we done

- We collected field data from 5 parcels in the summer of 2017 (like soil profiles, texture, organic matter content);
- We developed two 1D SWAP models, based on the collected field data;
- We simulated the current situation by calculating the hydrological years 2014 – 2017;
- We organized a meeting with our main stakeholder in order to discuss the gros list with potential measures (nov. 2017);
- We schematized the potential measures in the SWAP models and run different scenario's (measures, combination of measures and climate scenario's);
- The summer of 2018 we used to stress out the impact of climate change. Based on the calculated results we discussed the impact of climate changes and the potential measures with the stakeholders in a second meeting (nov. 2018).

What is still to be done

- We have to scale up the model results on parcel level to catchment level. Therefore we use the model WALRUS.
- Define the impact of the potential measures on water quality;
- Describe the final set of measures both based on the hydrological simulations as the input from the stakeholders.

QUANTITY INDICATOR

Baseline	The parcels on the flank of the river Dwarsdiep are sensitive to drought and intensive rainfall and will probable more sensitive in future. The single parcels are part of a bigger catchment and will therefore affect the downstream discharge of the catchment.
Target	The proposed measures should decrease the maximum dry stress in a situation like the summer of 2018 with 20% (relative to a situation with no measures).
Target time	Implementation of the proposed measures will be after the end of the Topsoil project.
Considerations	From a hydrological point of view we are able to define the impact of measures, but wether this impact is ultimately realized depends on the implementation by the farmers. And this itself depends also other aspects like costs, benefits and change needed in business management. Eventually it will take much more time to implement the measures.

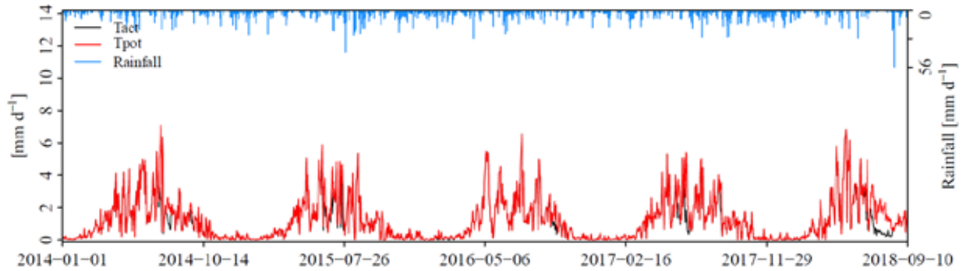
QUALITY INDICATOR

Baseline	The parcels on the flank of the river Dwarsdiep are sensitive to drought and intensive rainfall and will probable more sensitive in future. The single parcels are part of a bigger catchment and will therefore affect the downstream water quality. Especially the runoff of nutrients during intensive rainfall, will affect the surface water quality
Target	The proposed measures should improve the agricultural circumstances and therefore our target is that 20% less nutrients is used by the farmers.
Target time	Implementation of the proposed measures will be after the end of the Topsoil project.
Considerations	From a hydrological point of view we are able to define the impact of measures, but wether this impact is ultimately realized depends on the implementation by the farmers. And this itself depends also other aspects like costs, benefits and change needed in business management. Eventually it will take much more time to implement the measures. Besides the focus within our project is on the water quantity. Therefor we use different hydrological models. The derivative of that is the indicator for water quality. To what extent we have achieved the indicator for water quality we judge by expert judgement.

PARTNERS AND STAKEHOLDERS

Topsoil partners:
Waterschap Noorderzijlvest: Water authority - Arne Roelevink
Partners:
Consortium PB Land: Contractor
Wageningen University
Stakeholders:
Province Groningen
Westerkwartier: Local link between farmer and governmant
Staatsbosbeheer: Nature reserves management
Landowners

PRELIMINARY RESULTS

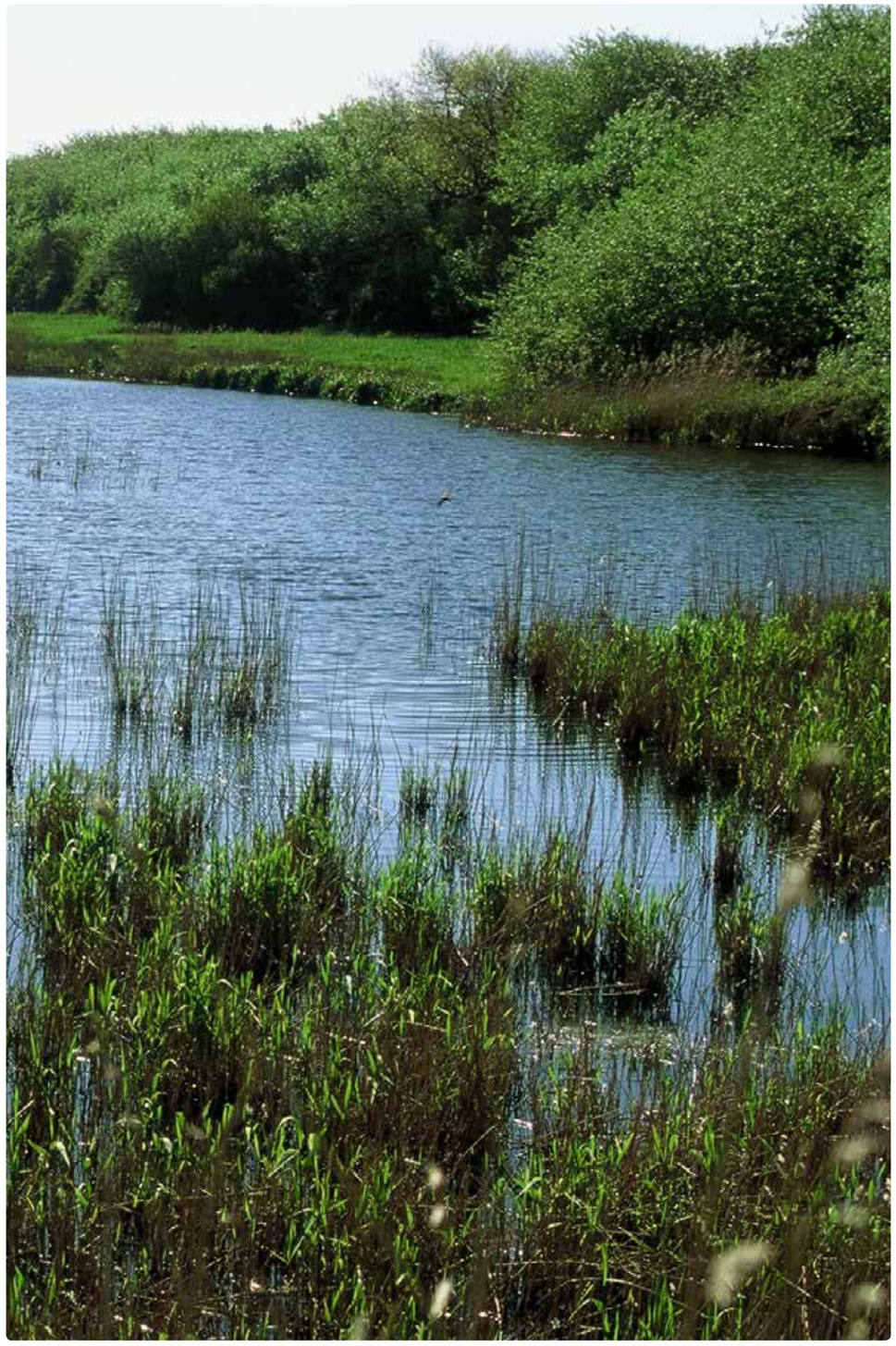


The calculated Transpiration actual ($T_{act.}$) with 1D SWAP model is not equal to the calculated Transpiration potential (T¬pot.) in the dry summer of 2018 due to the reduction of water up take by roots which causes dry stress. This matches perfectly with the experience of the farmers in this area.

Quote of one of the farmers during the last meeting with stakeholder in November 2018; If such a dry period will occur next year again, I have really a problem (see pictures below).

23th of August 2017 – 110 mm deficit

9th of August 2018 – 230 mm deficit



NL3

GEOTOP: investigation of the subsoil focusing on glacial till

CHALLENGES
- **Flooding**
- Saltwater intrusion
- **Groundwater buffer**
- **Soil conditions**
- Break down capacity

Background and objective

The objective of the project is to gain experience from using more detailed soil information and models to solve water problems on a regional and local scale. The available soil information (using existing boreholes and knowledge of the origin of the soils) will be compared with the principle of electromagnetic induction.

The aim of the project is to get a better understanding of the effect of climate change to groundwater on a regional scale. Because of the heterogeneous soil in Drenthe with less permeable layers just below the surface the impact of drought and heavy rain can differ from area to area. This will have an impact on both water quantity as on water quality.

What have we done

- Expert meeting with Aarhus University in Drenthe to discuss the possibilities of using electromagnetic methods
- Investigation for Nature2000 permit concerning the helicopter survey
- Cone penetration tests to be able to calibrate the electromagnetic measures
- Helicopter-borne electromagnetic survey
- Processing the electromagnetic data for the geophysical interpretation (by Aarhus University)
- Processing the geophysical data into a geological model (by TNO)
- Groundwater model (Simgro)

What is still to be done

- Geological model
- Resistivity maps
- Compare geological model with the groundwater model
- Calculations with the groundwater model

QUANTITY INDICATOR

Baseline	9,36 km2 belonging to 4 infiltration ponds
Target	Find additional 20% of the pilot Aa area (Drentse Aa) in which water infiltration will help to increase the available groundwater.
Target time	2019
Considerations	Measures will not be taken within the project. The expectation is that with future measures the infiltration will increase with 20% (> 2021).

QUALITY INDICATOR

Baseline	Current groundwater level within the N2000 area with groundwater dependent vegetation in 43,83 km2.
Target	In 20% of the N2000 area with groundwater dependent vegetation the groundwater level will rise compared with the autonomic trend due to the proposed measures.
Target time	2019
Considerations	Due to climate change the groundwater level in summer in the autonomic situation will lower. Due to the project the lowering will be less in 20% of the area.

PARTNERS AND STAKEHOLDERS

Topsoil partners:
Province of Drenthe
Partners:
Aarhus University: Geophysics - Jesper Pedersen
External partners:
Arcadis and TNO Advisory: Geophysical interpretation and geological model
Sweco Advisory and Querner Consult: Groundwater model

Stakeholders:
Water companies
Water authorities
Regional authorities
Farmers association

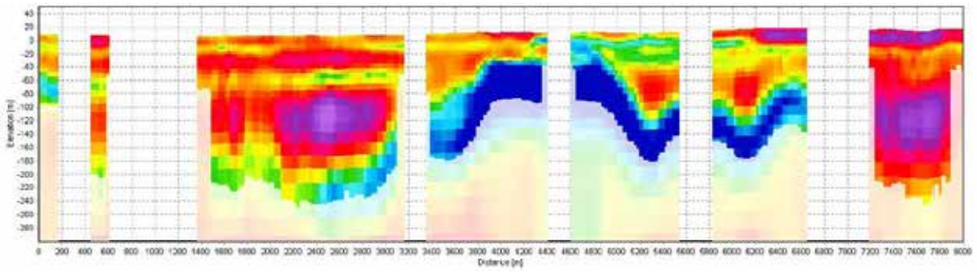
PRELIMINARY RESULTS

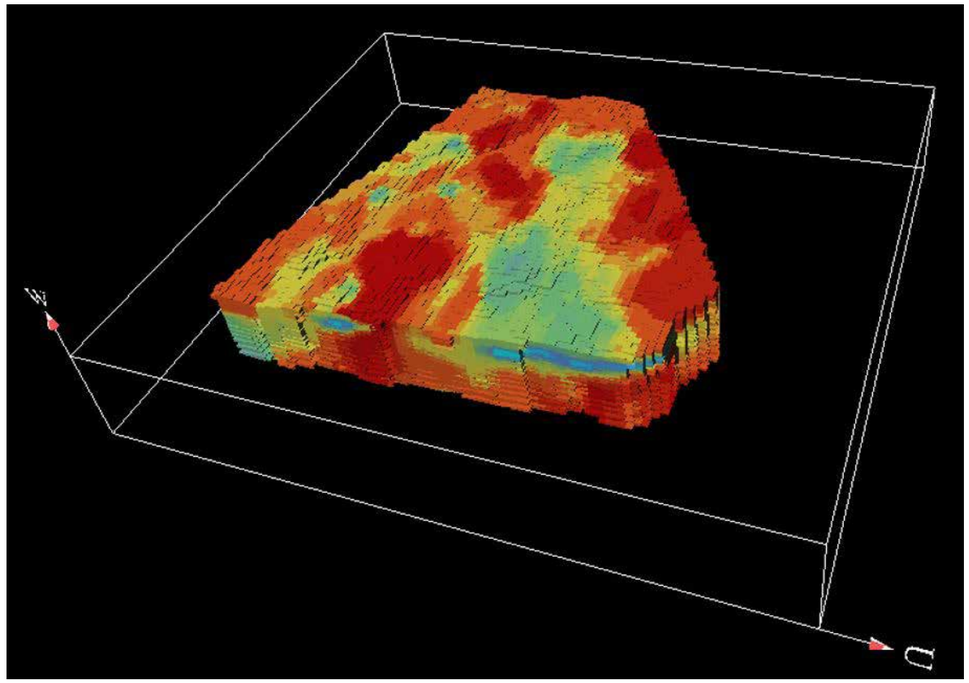
In 2017 the helicopter airborne survey with SkyTEM was finished and the Aarhus University started the processing of the data into three-dimensional resistivity maps of the subsurface. The soil resistivity had been mapped to a depth of 100 – 200 meters below terrain. The first results showed that the spreading of the meltwater till was different from what we knew from our geological maps. We could also see the upcoming of a saline dome in the north of the pilot area.

Further geological interpretation of the 3D-resistivity results will be carried out by TNO by adding information as boreholes and electrical conductivity logs. This will result in a detailed geological map and maps of conductance to be able to predict infiltration and run off.

One important issue is under investigation and that's the spreading of the so called "soft sands" which are part of the same formation. The resistance of these very consistent shaped round sands can be comparable to the till layers but can probably not be distinguished by the measured resistivity.

Modelling of the area has also started by improving an existing 7-layer model into a 20 layer model. This model should be able to predict the effects of drainage on the nature2000 area including climate change.





3D-resistivity

SkyTEM flights

UK 1

Water surface and groundwater connectivity and implication for water resource protection and management

CHALLENGES

- Flooding
- Saltwater intrusion
- Groundwater buffer
- **Soil conditions**
- **Break down capacity**

Background and objective

The principal objective behind UK1 is to gain a greater understanding of surface-groundwater interactions within the Wear catchment. Drinking water abstracted from the Magnesian Limestone (ML) aquifer is generally of good quality, with one exception exhibiting a rising trend in nitrate from an unconfirmed source; the investigation of which is included in the UK1 work programme. The ML groundwater (GW) body is currently at Poor status based on the Water Framework Directive classification because of a separate single point exceedance of the WFD limit of 50 mg/l as nitrate. The underlying Coal Measures GW body (Poor status: due to chemical impacts from legacy mining) underlies, and is in hydraulic connectivity with, the ML aquifer. Urbanisation, waste-water management, climate change leading to increased surface water flood risk, agriculture and historical industrial contamination, occurring in areas underlain by these GW bodies, potentially puts the ML aquifer at risk. Surface-groundwater connectivity maps, identifying possible GW and surface water (SW) interaction have been produced for the areas overlying the ML aquifer by the EA. Fracture flow within the ML aquifer is thought to be the dominant flow mechanism in the aquifer, and travel times are believed to be fast and afford little attenuation of rate of recharge or pollution. Opportunities to improve communication with key stakeholders, providing regulatory and direct integrated land and water management benefits, will be pursued through the Wear Catchment Partnership. New ways of working will be proposed through the Wear Catchment Business Plan 2018-2030.

What have we done

- PhD research of the Twizell and Lumley Park Burns
- PhD research of the Water-resource management in the UK
- Surface water quality sampling of Hawthorn Dene (on behalf of the EA)
- Surface water quality and flow sampling of Cut Throat Dene (on behalf of NW).
- Borehole investigation at a Sunderland public water supply Abstraction (in collaboration with NW)
- N-min testing & tissue sampling at the Seaham Grange Farm field trial.
- Stakeholder engagement targeting areas at high risk of infiltration to groundwater
- Pilot Storymap (in collaboration with Partners, initially focusing on the 2017 Hawthorn investigation. To be rolled out to other areas.
- Initial review of land & water governance, requiring further discussion to inform the development of an improved catchment management regime.

QUALITY INDICATOR

Baseline	Wear Magnesian Limestone GW body is at Poor status and overlying surface water bodies are at Poor to Moderate status with the River Basin Management Plan cycle 2, 2015 as baseline. Surface waterbodies flow across relatively deep and also very shallow areas of glacial drift with corresponding variable risk of infiltration.
Target	20 % improvement across 10 individual surface waterbodies' ecological classification elements against River Basin Management Plan cycle 2, supporting WFD objectives to 2027. This approach is a surrogate for direct groundwater quality estimates.
Target time	Completion of River Basin Management Plan cycle 3, 2027
Considerations	Physical Magnesian Limestone groundwater quality is difficult to consistently estimate, given the variability of results from closely located boreholes. Recharge and pollution pathways are believed to be strongly influenced generally and locally by fracture flows

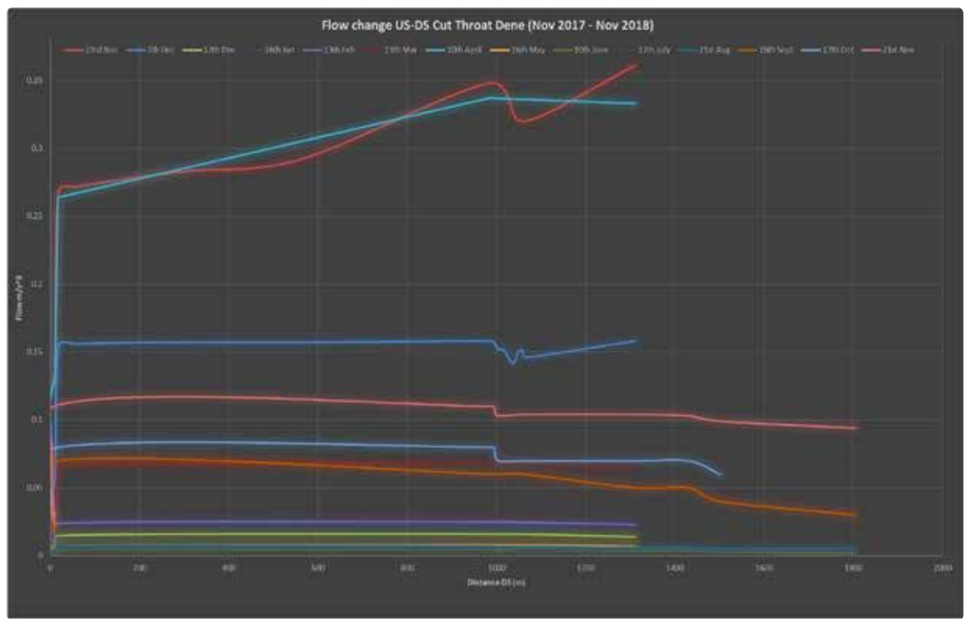
PARTNERS AND STAKEHOLDERS

Topsoil partners:
Wear Rivers Trust
Northumbrian Water (NW)
Durham University
External partners:
Environment Agency (EA)
Heritage Coast Partnership
Stakeholders:
Seaham Grange Farm
Frontier Agriculture Ltd.
Landowners
Regulators
Strategic Planners
Wear Catchment Partnership
Land and Water Managers

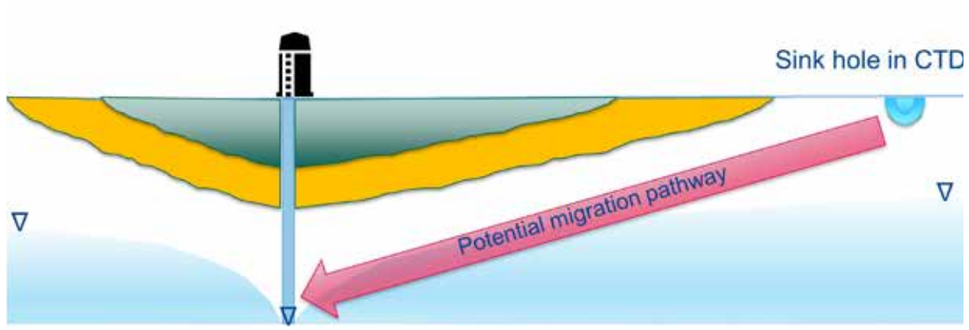
PRELIMINARY RESULTS

Summary of results: groundwater monitoring at a NW abstraction highlights a stepped increase in nitrates after heavy storm events and does not fall back. The investigation has so far eliminated sewer network leakage and a nearby site for nesting birds as potential sources of elevated nitrate. Exploration continues into other potential sources of nitrate, including historic landfills and agriculture. Other investigations into GW/SW interaction continue with the technical study of near surface contaminants on the Twizell Burn through PhD researcher R. Smith and on the Hawthorn Dene by the WRT and the EA. The Hawthorn Dene investigation is being used as a pilot for the development of the Storymap project, an online information repository and interactive visual communication aid. PhD researcher V. Smith is currently investigating the current state of collaborative water resource management in the Wear Catchment using social network analysis and agent-based modelling to evaluate the impact of the Catchment Based Approach. Targeted farming network events are raising awareness of the integrated nature of land and water management whilst highlighting risks to groundwater from soil infiltration and surface water pollution through "leaky" stream beds.

Highlight: Cut Throat Dene (CTD) (an ephemeral stream) has recently been connected to overflows from Boldon Flatts, a wetland bird reserve that is also grazed by cattle and horses. Initial results of chemical sampling confirm high coliform counts entering from Boldon Flatts as well as urban pollution and agricultural inputs from further upstream. The CTD flows over reported 'sink holes' within the stream bed and directly above a highly fractured ML aquifer. There is the potential for pollutants present in the CTD establishing a pathway through the sink holes and being drawn back into the public supply. Current evidence indicates no connection is present. Tracer tests are planned to confirm this lack of connectivity. Flow monitoring has confirmed SW losses around 900-1000m down stream of the public water supply abstraction, in the vicinity of the suspected sink holes (Figures below).



Recorded flow losses within the Cut Throat Dene (2018).



Conceptual model of CTD, displaying the NW borehole and suspected sink holes ~900 m downstream of the abstraction.

UK 2

Holistic water and soil management in East Anglia

CHALLENGES
- **Flooding**
- Saltwater intrusion
- **Groundwater buffer**
- **Soil conditions**
- **Break down capacity**

Background and objective

East Anglia is one of the driest regions in Europe but heavily reliant on water to support agriculture, nature and an increasing population. The aim of the pilot is to deliver a series of sub-projects that demonstrate the benefits of a more holistic approach to the management of soil, groundwater and surface water in the context of climate change and catchment management.

Principal sub-projects include:

- Reducing sediment input into important (N2k site & drinking water) reservoir
- Managed Aquifer Recharge (MAR) – Storage of excess winter surface water in the aquifer for crop irrigation the following summer
- Groundwater catchment plans – working with stakeholders to develop common understanding of GW systems and developing management plans for public supply boreholes
- Water Sensitive Farming– improving soil health, reducing soil and nutrient loss and increasing water infiltration.

What have we done

- Working with water companies to deliver groundwater protection advice to farmers
- Developing ArcGIS online groundwater and water resources 'story maps'
- Infiltration trials in advance of proposed Managed Aquifer Recharge scheme
- Investigations into sediment pathways
- Field trials to investigate the benefits of tramline disruption technology to reduce soil and water loss
- Farming/best practice knowledge exchange events
- Delivery of farm interventions

What is still to be done

- Develop conceptual models of water and soil retention
- Deliver Managed Aquifer recharge trial
- Further scaling up of cross-sector groundwater protection approaches

QUALITY INDICATOR

Baseline	Reduced contaminants (e.g. sediment, nutrients and pesticides) entering aquatic receptors (surface and groundwater).
Target	Reduction in nutrient and pesticide levels available to leach into groundwater Reduction in soil loss from fields to surface water
Target time	2025
Considerations	Farmer and land owner involvement is essential in these targets. Another key consideration is the simplification and sharing of groundwater models.

QUANTITY INDICATOR

Baseline	Increased water retention/infiltration/aquifer recharge
Target	Increased recharge through artificial Managed Aquifer Recharge scheme Great water retention within soils from improved soil management
Target time	2019
Considerations	Aquifer recharge scheme is dependent on consent from the environmental regulator.

PARTNERS AND STAKEHOLDERS

Topsoil partners:
The River Trust (RT): Coordinating partner - Barry Bendall, Barry@therivertrust.org
Essex & Suffolk Rivers Trust (ESRT): Partner - Jane Herbert, jane@essexsuffolkriverstrust.org
Norfolk River Trust (NRT): Partner - Ed Bramham-Jones, ed@nordfolkriverstrust.org
Contributing partners and stakeholders:
Anglian Water
Essex & Suffolk Water
CamEO Catchment Partnership
Broadland Rivers Catchment Partnership
East Suffolk Catchment Partnership
WWF UK
Coca-Cola GB

PRELIMINARY RESULTS

Key results so far have included;
- Developing a new collaborative approach to protecting public supply groundwater resources. The work involved one-to-one farmer engagement, developing an understanding of groundwater models and identifying potential changes in farming practices that could increase the resilience of the groundwater to water quality deterioration.
- Completion of a field trial to investigate the benefits of different tramline disruption techniques in potato fields. Previous work has demonstrated that as much as 80% of water and soil loss from fields is from tramlines and this current trial demonstrated that significant reductions in soil and water loss can be achieved when mechanical disruption techniques were applied.
- Completion of a field trial to demonstrate the efficacy of a Managed Aquifer Recharge project aiming to store excess winter surface water in the aquifer to buffer water availability the following summer. The trial is due to take place early in 2019.

Site of the proposed Managed Aquifer Recharge trial in Suffolk, UK. Picture shows the headworks of monitoring borehole and the established grassland on the left of the field and the newly planted ryegrass to the right. The trial will investigate the recharge of directly applied water to the soils at both locations.

Tramline disruption technology being trialled in a potato crop on the Elveden Estate, UK.

List Partners

Project partners

The **Topsoil project** has been set up under the Interreg North Sea Region programme. This is a transnational programme aimed at supporting, developing and promoting sustainable economic growth in the participating countries in the North Sea Region. Cross-border cooperation is essential because climate change does not stop at national borders.

The Netherlands

Waterschap Hunze en Aa's
Waterschap Noorderzijlvest
Provincie Drenthe

Germany

Bundesanstalt für Geowissenschaften und Rohstoffe
Dachverband Feldberegnung Uelzen
Landwirtschaftskammer Niedersachsen
Landesamt für Bergbau, Energie und Geologie
Leibniz-Institut für Angewandte Geophysik
Oldenburgisch-Ostfriesische Wasserverband
Landesamt für Landwirtschaft, Umwelt und ländliche Räume Schleswig-Holstein
Universität Bremen Geologischer Dienst für Bremen

Belgium

Vlaamse Milieumaatschappij

Denmark

Region Midtjylland (leadpartner)
Region Syddanmark
Herning Kommune
Horsens Kommune
Hydrogeofysik Gruppen, Geoscience Aarhus University
De Nationale Geologiske Undersøgelser for Danmark og Grønland

United Kingdom

Rivers Trust
Norfolk Rivers Trust
Essex & Suffolk Rivers Trust
Northumbrian Water Ltd.
Durham University

References

Reports and publications:

2016

- Kleijberg, R., De Koning, N., Interreg project Topsoil provincie Drenthe, Voortoets Natuurbeschermingswet, Arcadis, 16 augustus 2016, The Netherlands.
- Waterloo,M. J. , Gaast van der, J., Velstra, J. , Osté,A., 2016, Nutriënten en gewasbeschermingsmiddelen, 20 December 2016, Interreg Topsoil Project, RPS, Leerdam, The Netherlands.

2017

- Burger, S., Groen, M.,Velstra, J., 2017, Geofysisch onderzoek toepasbaarheid SKYTEM, 04.01.2017, Acacia Water , Gouda , The Netherlands
- Data report SkyTEM Survey: Drenthe, Netherlands, May 2017, SkyTEM, Denmark.
- Pedersen, J. B., Auken, E., Christiansen, A. V., Blæsbjerg, H., Johnsen, R., Pedersen, J., Rasmussen, K., Møller, R. R., & Mogensen., M., GCM Mapping Gedved, Report number 23-06-20 17, June 2017.
- Pedersen, J. B., Auken, E., Christiansen, A. V., Fiandaca, G. , Ejlertsen, S., Dath, S. & Specht., A., GCM Mapping Elev, Report number 06-06-20 17, June 2017.
- Pedersen, J. B., Auken, E., Christiansen, A. V., Fiandaca, G. , Ejlertsen, S., Dath, S & Specht., A., GCM Mapping Vildbjerg, Report number 06-06-20 17, June 2017.
- Pedersen, J. B., Auken, E., Foged, N., Grombacher, D., Veen, R. V. & Vree, L., SkyTEM survey Drenthe, Report number 15-06-20 17, June 2017.
- Waterloo,M. J. , Gaast van der, J., Velstra, J. , Kruisdijk, E., Osté, A., 2017, Duurzame Waterkwaliteit Drenthe, 5 mei 2017, Rapportage stap 1 Fase 1 Interreg Topsoil project, RPS, Leerdam, The Netherlands.
- Wiederhold, H., Rahman, M.A., Grinat, M., Kirsch, R. & Scheer, W., 2017, The Topsoil project - Integrated approach of near surface geophysics and groundwater modelling. Extended Abstract, EAGE Near Surface Geoscience, 03.-07.09.2017; Malmö, Sweden.

2018

- Bruns, M., Stiller, B., Schmedding, H.: Neue Ansätze zur überregionalen Bewirtschaftung von Grundwasserleitern. Wasser und Abfall, Heft 9, 2018, Wiesbaden.
- Kirsch R (2018): Geophysical works in the Topsoil area GE1 – VES data interpretation and petrophysical characterisation. Internal report, LLUR-SH.
- Maurya, P.K., Auken, E., Christiansen. A.V., Foged, N. and Eiskjær, T.T., 2018, A New Towed Ground-Based TEM-System for 3D Mapping of the Top 50 Meters of The Subsurface: 24th European Meeting of Environmental and Engineering Geophysics, Porto, Proceedings. DOI: 10.3997/2214-4609.201802504.
- Pedersen, J.B., Maurya, P., Auken, E. and Christiansen, A.V., 2018, tTEM Mapping Varde pilot, Report number 31-5-2018, May 2018, Aarhus University.
- Pedersen, J.B., Maurya, P., Kraghede, R., Engebretsen, K., Auken, E. and Christiansen, A.V., 2018, tTEM Mapping Sunds pilot, Report number 05-03-2018, March 2018, Aarhus University.
- Pedersen, J.B., Maurya, P. and Eiskjær, T., 2018, FloaTEM Mapping Sunds lake, Report number 06-11-2018, November 2018, Aarhus University.
- Pedersen, J.B., Maurya, P., Kraghede, R., Engebretsen, K., Auken, E. and Christiansen, A.V., 2018, tTEM Mapping Gedved pilot, Report number 05-03-2018, March 2018, Aarhus University.
- Pedersen, J.B., Maurya, P., Kraghede, R., Engebretsen, K., Auken, E. and Christiansen, A.V., 2018, tTEM Mapping Elev pilot, Report number 05-03-2018, March 2018, Aarhus University.
- Pedersen, J.B., Maurya, P., Kraghede, R., Engebretsen, K., Auken, E. and Christiansen, A.V., 2018, tTEM Mapping Vildbjerg pilot, Report number 05-03-2018, March 2018, Aarhus University.
- Rahman, M.A., González, E., Wiederhold, H., Deus, N., Elbracht, J. & Siemon, B. (2018): Characterization of a regional coastal zone aquifer using an interdisciplinary approach – an example from Weser-Elbe region, Lower Saxony, Germany. Extended Abstract, 25. Salt Water Intrusion Meeting, 18.-22.06.2018; Gdansk, Poland.
- Wear Catchment Partnership, 2018. The Wear Catchment Partnership Business Plan.
- Wiederhold, H. (2018): Reflexionsseismische Untersuchungen - Scherwellenseismik Schillerslage. - Kurzbericht für Projekt Topsoil, LIAG-Bericht, Archiv-Nr. 0135310; Hannover.

Poster presentations:

2016

- Smith, R., Bracken, L.J. and Wainwright, J., 2016, Understanding Groundwater-Surface Water Connectivity. Poster, HYTECH Interfaces within aquatic ecosystems' Symposium, 29.-30.08.2016; Aberdeen, UK.
- Smith, V., Bracken, L.J., and Wainwright, J., 2016, New ways to think about managing water resources: The role of gender. Poster, HYTECH Interfaces within aquatic ecosystems' Symposium, 29.-30.08.2016; Aberdeen, UK.

2017

- Andrews, G., Colling, M. 2017. Topsoil Banner: Surface water / Groundwater interactions. (20/09/2017); Brancepeth Castle, Durham, UK.
- Johnsen, Rolf et al.; AquaConSoil Conference, Postersession 6B.01 no. 678: "Topsoil Resilient soil and water resources, understanding the water beneath your feet", 27.06.2017 Lyon, France.
- Noell, U., Stadler, S. (2017): Limiting nitrogen and veterinary pharmaceutical input into groundwater: combining hydrogeophysics and soil science. EGU, 23-28.4.2017, Vienna, Austria.
- Smith, R., Bracken, L.J. and Wainwright, J., 2017, Understanding Groundwater-Surface Water Connectivity and Interactions in Heavily Modified Rivers. Poster, British Society for Geomorphology (BSG) Annual Meeting, 04.-06.09.2017; Hull, UK.
- Stadler, S., Noell, U., Stange, C. F. 2017: Understanding heterogeneities of flow paths for agricultural practice. Jahrestagung der Deutschen Bodenkundlichen Gesellschaft, 2.-7.9.2017. Göttingen, Germany.
- Vandevelde, D, 2016. Increasing the availability of freshwater for agriculture by improving local hydro(geo)logical conditions. Poster, Salt Water Intrusion Meeting, 04.-08.07.2016; Cairns, Australia.
- Wiederhold, H., Elbracht, J., Scheer, W., Deus, N., Sinnwell, E., Rahman, M.A. & Kirsch, R., 2017, Projekt Topsoil: Boden und Grundwasser in der Elbe-Weser-Region und der Störmarsch im Klimawandel. Poster, 35. Jahrestagung des Arbeitskreises 'Geographie der Meere und Küsten', 19.-22.04.2017; Kiel, Germany.
- Wiederhold, H., Rahman, M.A., Grinat, M., Kirsch, R. & Scheer, W., 2017, The Topsoil project - Integrated approach of near surface geophysics and groundwater modelling. Poster, EAGE Near Surface Geoscience, 03.-07.09.2017; Malmö, Sweden.

2018

- Colling, M. Feb 2018. Farming Up North (FUN): Topsoil project leaflet. (01/02/2018), Rushyford, Durham, UK.
- Colling, M. Mar 2018. Magnesian Limestone Rural Diffuse Project: Topsoil project leaflet. (13/03/2018), Bowburn Hall, Durham, UK.

- González, E., Deus, N., Elbracht, J., Azizur Rahman, M., Wiederhold, H. & Siemon, B., 2018, Topsoil – Grundwasserversalzung in der Elbe-Weser-Region. Poster, Tagung der FHDGGV, 21.-24.03.2018, Bochum, Germany.
- González, E., Deus, N., Elbracht, J., Siemon, B. (2018): Large-scale geological structure model of the Elbe-Weser Region. Central European Conference on Geomorphology and Quaternary Sciences, 23.- 27.09.2018; Giessen, Germany
- Noell, U., Fishkis, O., Lamparter, A., Stadler, S. (2018): Multidisciplinary Study of Infiltration Processes. Jahrestagung der Deutschen Geophysikalischen Gesellschaft. Leoben, Österreich, 12. - 15.02.2018.
- Rahman, M.A., Wiederhold, H., Stadler, S., Koeniger, P., Winter, S. & Siemon, B. (2018): Subsurface characterization of a fresh water lens barrier island using geological, geophysical, geochemical and hydrological data - case study Borkum, Germany. Poster, European Geosciences Union, 09.-14.04.2018; Wien, Austria.
- Smith, R., Bracken, L.J. and Wainwright, J., 2018, Integrated River Evaluation for Management (IREM): A novel approach to understanding the role and impact of groundwater-surface water interactions on in-stream water quality. Poster, The River Restoration Centre (RRC) Annual Conference, 24.-25.04.2018; Nottingham, UK.
- Veen, R. van, De Verdieping "Verdieping van Kennis, Producten en Toepassingen", ICC Congres 2017, 7 juni 2017, Amsterdam, The Netherlands.
- Wiederhold, H., Scheer, W., Kirsch, R., Rahman, M.A., Ronczka, M., Grinat, M. & Siemon, B. (2018): Saltwater intrusion under climate change in North-Western Germany - mapping, modelling and management approaches in the projects Topsoil and go-CAM. Poster, 25. Salt Water Intrusion Meeting, 18.-22.06.2018; Gdansk, Poland.

Oral presentations:

2017

- Melvej, Anja; Henrik Larsen; Rolf Johnsen; Anders Juhl Kallesøe; Thomas Gad; Benny Nielsen; Jesper Bjergsted Pedersen; AquaConSoil Conference, Session 6b.1 – "Water and subsurface management in the context of climate change". Presentation: "High groundwater table in a Danish town – Challenges and opportunities in a climate adaptation perspective" 30.06.2017; Lyon, France.
- Specht, Anette, Johnsen, Rolf, Blæsbjerg, Helle, Pedersen, John and Pedersen, Jesper; AquaConSoil Conference, Session 1d.1: "Geophysical and geostatistic methods in site characterization". Presentation: "Improvement of traditional investigations by prior geophysical measurements" 29.06.2017 Lyon, France.
- Colling, M. Dec 2017. Cut Throat Dene: Sampling update. (06/12/2017) Wear Rivers Trust, UK.
- Colling, M. Dec 2017. Hawthorn: Sampling update (06/12/2017) Wear Rivers Trust, UK.

2018

- Auken, E., Christiansen, A. V., Pedersen, J. B., Foged, N. & Eiskjær, T., 2018, A NEW TOWED GROUNDBASED TEM SYSTEM FOR 3D IMAGINING OF THE TOP 70 METER OF THE SUBSURFACE, SAGEEP, March 2018, Nashville, USA.
- Auken, E., Pedersen, J. B., Christiansen, A. V., Vilhelmsen, T. V. & Foged, N., 2018, A new towed groundbased TEM system for 3D imaging of hydrogeological structures, Danish Water Forum, January 2018, Denmark.
- Christiansen, A. V., Pedersen, J. B., Auken, E. & Madsen, L., 2018, tTEM - Et nyt instrument til ekstrem detaljeret kortlægning af den overfladenære geologi til geotekniske undersøgelser, grundvandsbeskyttelse og landbrug, Annual ATV meeting, March 2018, Vingsted, Denmark.

- Colling, M. Mar 2018. Hackerthon: How end users utilise data from the EA in their projects. (14/03/2018). Sunderland, UK.
- Deus, N., González, E., Azizur Rahman, M., Siemon, B. & Wiederhold, H., Validation of HEM-based mapping of the salt-/freshwater interface (SFI) using Direct-Push groundwater sampling. ARGE Grundwasserversalzung/Topsoil groundwater salinization workshop, 06.-07.03.2018, Bremen, Germany.
- Deus, N. & González, E. (2018): HEM-basierte Kartierung der Salz-/Süßwassergrenze an der niedersächsischen Küste & Einblick in das EU-Interreg Projekt Topsoil. Hauskolloquium Geozentrum Hannover, 10.04.2018.
- Hudson, S. April 2018. Magneisan Limestone Rural Diffuse Project: Soil Health Farming Demonstration (05/04/2018) Seaham Grange Farm, Durham, UK.
- Hudson, S. Feb 2018. Magneisan Limestone Rural Diffuse Project Overview. (13/03/2018) Bowburn hall, Durham, UK.
- Pedersen, J. B., Auken, E., Christiansen, A. V., Vilhelmsen, T. V. & Foged, N., 2018, A new towed groundbased TEM system for 3D imaging of hydrogeological structures, Danish Water Forum, January 2018, Denmark.
- Rahman, M.A., González, E., Wiederhold, H., Deus, N., Elbracht, J. & Siemon, B. (2018): Characterization of a regional coastal zone aquifer using an interdisciplinary approach – an example from Weser-Elbe region, Lower Saxony, Germany. 25. Salt Water Intrusion Meeting, 18.-22.06.2018; Gdansk, Poland.
- Rahman, M.A., Wiederhold, H., Grinat, M., Scheer, W., González, E., Deus, N. & Elbracht, J. (2018): Analysis of salinity distribution in the coastal aquifer of northern Germany using geophysical and geochemical information. ARGE Grundwasserversalzung & Topsoil Workshop on groundwater salinisation, 06.-07.03.2018; Bremen, Germany.
- Scheer, W., Kirsch R., Wiederhold, H., 2018, Groundwater in a changing climate – consequences for the North Sea region. Master course integrated environmental management, Christian-Albrechts-Universität Kiel, Germany.
- Schmedding, H.: Neue Ansätze zur überregionalen Bewirtschaftung von Grundwasserleitern in Zeiten veränderter Anforderungen. Bund der Ingenieure für Wasserwirtschaft, Abfallwirtschaft und Kulturbau (BWK) Bundeskongress Lüneburg 21.9.2018.
- Smith, R. Mar 2018. Collaborative Water Resource Management. UK 1 Partner Meeting. (12/03/2018) Durham University, UK.
- Smith, R. Mar 2018. Integrated River Evaluation for Management: The Twizell Burn. UK 1 Partner Meeting. (12/03/2018) Durham University, UK.
- Smith, V., Wainwright, J., and Cunningham, N., 2018, Analysis of the current state of collaborative water-resource management in the UK using SNA and ABM: case study in the Wear catchment. Presentation, RGS Midterm Conference, 18.-20.04.2018; Royal Holloway, University of London, UK.
- Smith, V., Wainwright, J., and Cunningham, N., 2018, Analysis of the current state of collaborative water-resource management in the UK using SNA and ABM: case study in the Wear catchment. Poster, XXXVIII Sunbelt Conference, 26.06-01.07.18; Utrecht, The Netherlands.
- Wiederhold, H. (2018): Küstenaquifere im Klimawandel – aktuelle Entwicklungen aus den Projekten (NAWAK), go-CAM und Topsoil. Arbeitstreffen „Klimaanpassung – Meeresspiegelanstieg – Versalzungszonen", 11./12.04.2018; BGR Hannover.
- Waterloo, M. J., 2018, SWAP and SWAT modelling of the brooks Drentsche Aa and Hunze. 09.03.2018; Bremen, Topsoil meeting; Acacia Water, Gouda, The Netherlands.

Notes

Midterm Catalogue