

SE1: Preventing the brownification of lake water

Lund University, Sydvatten, Geological Survey of Sweden

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Mitigate the brownification of lake water

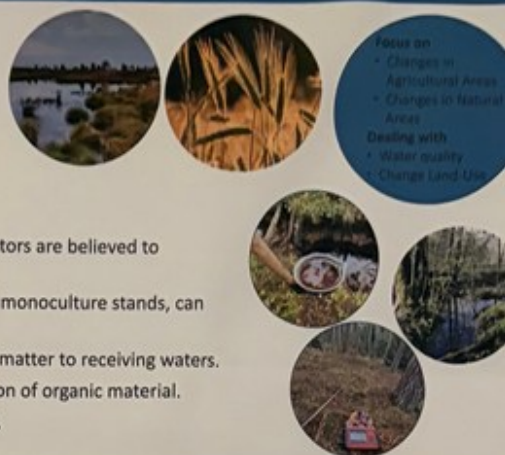
Problem:

The brownification of lake water poses major challenges for drinking water producers and lake biodiversity, leading to higher treatment costs and declining biodiversity.

Causes and drivers for brownification:

The causes of brownification are complex and not yet fully understood. However, several factors are believed to contribute:

- Unsustainable forest management practices, such as unsuitable species composition and monoculture stands, can increase the flux of dissolved organic matter (DOM) into surface waters.
- Drainage systems, including ditches, promote faster and more direct transport of organic matter to receiving waters.
- Climate change and extreme weather events can increase water discharge and mobilization of organic material.
- Leakage of dissolved organic matter from peat bogs further contributes to brownification.



Our strategy to foster a Blue Transition

Potential solutions to mitigate brownification include creating wider and more extensive riparian buffer zones, improving water management practices in forested landscapes, and increasing understanding of the complex hydrogeological system. In addition, rewetting drained wetlands and peatlands can help reduce the leakage of dissolved organic matter into surface waters.

Continuous stakeholder dialogue and knowledge sharing are essential for building trust, securing support, and ensuring successful implementation of measures to reduce brownification. Investigating how and why measures work helps close knowledge gaps and improve management strategies. A monitoring system is also crucial to assess both intended and unintended effects of rewetting over time.

Achievement

During the Blue Transition project, several results were achieved across multiple levels, including extensive geophysical and hydrogeological investigations, stakeholder collaboration through workshops, presentations, and policy days, and the development of a strategic framework. In addition, outreach activities such as a summer school and several master's theses were carried out, and a rewetting testbed was established.

Summer school



Impressions from the summer school Trondheim 2025.

Stakeholder involvement



Impressions from the regular stakeholder meetings.

Master theses



Two exemplary master theses from the pilot.

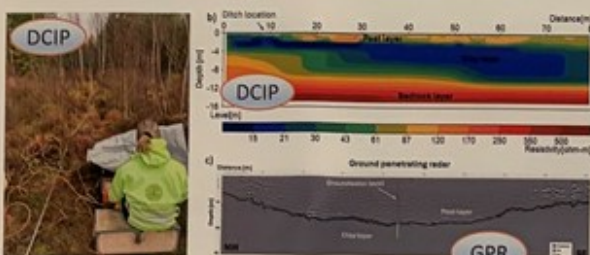
Plönninge testbed

Setup of a monitoring system to track intended and unintended consequences of rewetting



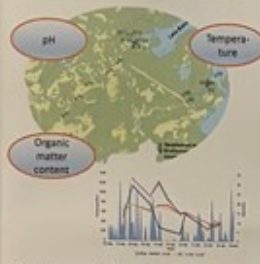
Time plan for the Plönninge testbed before, during and after rewetting.

Geophysical & hydrogeological investigations



Impression (a) and measurement results for DCIP (b) and GPR measurements (c).

Lake water sampling



Exemplary results from lake and river water sampling and color measurements.



Map of testbed Plönninge (a), photos from testbed (b, c) and exemplary groundwater observation wells results (d).

Challenges

Limited understanding of the drivers and ecological effects of brownification, together with a lack of long-term datasets, highlights the need for further research. Although land-use change is important for mitigating brownification, implementation is challenging due to the many private landowners involved around Lake Bolmen (> 1000!) and the time required to build trust and stakeholder collaboration. In Sweden's non-profit drinking water sector, economic incentives for water protection are limited, while the implementation of effective mitigation measures is further complicated by long-lasting drainage ditch permits.

Outlook

- Conduct further research at the Plönninge testbed to investigate the effects of rewetting
- Maintain continuous collaboration with stakeholders
- Promote knowledge sharing among relevant actors
- Secure funding to continue and expand research on this important topic



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Priority 3.0
Climate resilience
and biodiversity



Improving Hydrogeological Understanding and Sustainable Water Management in the Vomb Area

Challenges

In the face of future climate change, southern Sweden (Figure 1a) is expected to experience more frequent droughts, heavy rainfall, and temperature extremes. The Vomb Trough (Figures 1b and c) contains one of the largest combined aquifers in southern Sweden and includes important wetlands and lakes, such as the Klingavälsån Valley and Lake Vomb. Increased surface and groundwater extraction, combined with climate change, is likely to affect the region's water supply, biosphere, and biodiversity.

In our pilot, we aimed to achieve the following goals:

- Enhance hydrogeological understanding between the Vomb aquifers, wetlands, and lakes.
- Improve artificial infiltration at the MAR plant (Figures 1c and d).
- Develop a conceptual hydrogeological model.
- Support sustainable water management in the Vomb area.

Our strategy to foster a Blue Transition

Sustainable water management in the Vomb Trough requires a solid understanding of groundwater and its interaction with surface water under increasing climate and demographic pressures. This project establishes a technical and monitoring baseline for long-term, adaptive management. Monitoring the MAR infiltration pond provides key insights into recharge efficiency, subsurface flow, and storage in a complex geological setting. Together with initial modelling, it lays the foundation for optimizing MAR operations and supporting a resilient Blue Transition.

Achievements

Vomb Trough

- Background hydrogeological data were collected and processed to develop a model of the Vomb Trough
- Groundwater levels from 16 high-accuracy observation wells were used for baseline and model calibration (Figure 4).
- A conceptual model was developed using SkyTEM data and groundwater measurements

Wetland Dynamics

- Wetland dynamics were monitored using integrated hydrological and geophysical methods.
- DCIP surveys were conducted at multiple time steps to assess changes in subsurface moisture and resistivity (Figure 5).
- GPR profiles characterized the shallow stratigraphy, showing an 80 cm organic soil layer over sandy soil (Figure 5).

Vomb Water Works

- A comprehensive monitoring system was installed in the MAR infiltration pond at Vomb Water Works, including continuous geoelectrical tomography, temperature, groundwater levels, and soil moisture measurements (Figures 2 and 3).
- Groundwater mounding effects were successfully measured and visualized, leading to better management of the infiltration pond.
- Long-term monitoring is successfully ongoing, enabling detailed observation of seasonal variations and system development

Next steps

Stakeholders

Municipalities & Planners: Sustainable supply planning; prepare for increased extraction

Environmental Agencies: Protect ecosystems; assess biodiversity impacts

Researchers & Consultants: Use data for modelling and MAR research

Vomb Water Works: Optimize infiltration; improve recharge and water quality

Future Projects

3D Groundwater Model: Predictive model with climate scenarios

Wetland-Aquifer Study: Long-term monitoring; expand geophysics

Climate & Blue Transition: Demand management + nature-based solutions



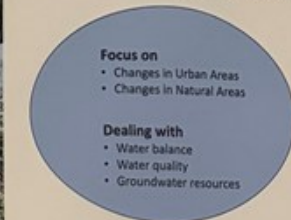
Figure 1: Location details of the study area (not to scale): (a) Sweden, with highlighted Scania; (b) borders of Scania municipalities highlighted with Vomb trough; (c) Vomb trough highlighted with Vomb Water Works and Vomb Lake; (d) Vomb infiltration pond.



Figure 2: Installation of the electric cables and electrodes of monitoring system



Figure 3: Soil Moisture sensor towards the inlet



Focus on

- Changes in Urban Areas
- Changes in Natural Areas

Dealing with

- Water balance
- Water quality
- Groundwater resources



Figure 4: Extraction of groundwater level data from new wells

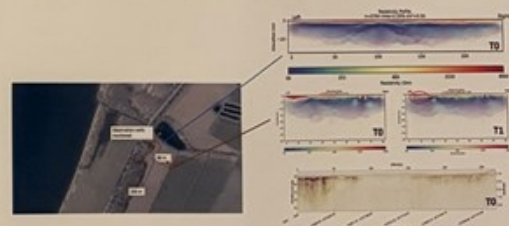


Figure 5: Wetland monitoring with indicated observation wells in the area and time steps of DCIP results with GPR



GE1: Luneplate

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Climate adapted water management to prevent saltwater intrusion and desiccation of organic loam with the associated CO2 submission

The Luneplate area in southern Bremerhaven is highly vulnerable to climate change impacts, particularly saltwater intrusion and soil desiccation. The region combines protected natural areas, intensive agriculture, and future economic development within a sensitive hydrological system.



The goal is to develop climate-adapted water management strategies that protect groundwater resources, prevent soil degradation, and reduce CO₂ emissions from drying organic soils.



The challenges were balancing competing land uses under changing climate conditions, including increasing heavy rainfall, rising sea levels, and shifting groundwater dynamics. In addition there were a number of administrative constraints such as strict legal requirements for infiltration.

Our strategy to foster a Blue Transition



The main objective of the strategy is to maintain groundwater recharge at the highest possible level in order to counteract the expected increase in saltwater intrusion due to climate change. To establish a scientific basis for this approach, the study area was systematically mapped with geophysical measurements and groundwater monitoring to determine the current location of the freshwater-saltwater interface.



Our long term strategy focuses on integrated rainwater management, including rainwater collection, temporary storage and infiltration to counteract saltwater intrusion.

Working closely with government agencies, planners, and regional stakeholders, we aim to implement infiltration concepts and ensure that the proposed measures are compatible with future urban and economic development. The strategy focuses on high-pressure infiltration systems, which are particularly well-suited for densely populated urban areas.

Achievement



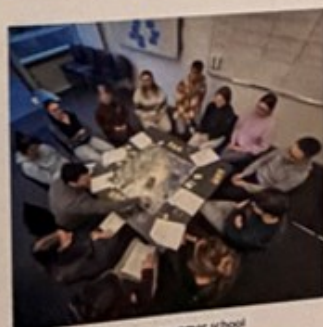
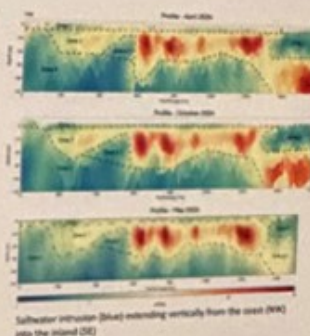
Improved understanding of saltwater distribution and dynamics of coastal aquifers under climate change through

- Geophysical measurements with the LIAG institute (Hanover) to map the dynamics of salt-freshwater interface which serve as a basis for
- 3D-geological model and numerical groundwater flow model to simulate various groundwater management scenarios under the conditions of climate change



Innovative communication tools for collaboration between science, policy, authorities and inhabitants

- Image film with INTERREG
- Summer School "Climate Change and Groundwater Management in Bremerhaven: Impacts and Long-Term Adaptation Strategies"
- Water management game "Aqua strategists, the groundwater managers"
- Augmented reality with Danish project partners from VIA University College to show climate change impact and the effect of our strategies in our pilot on site



"Aqua Strategists" at the summer school



Remaining challenges:
Transferring pilot results into long-term and large-scale implementation under regulatory, institutional, and multi-stakeholder constraints.



Future uptake:

- Continued collaboration with stakeholders and public authorities
- Integration of results into future planning and follow-up projects
- Further development of governance and implementation strategies for climate-resilient water management



Conceptual model for groundwater monitoring at the test location site Luneplate (April 2020 - May 2021)

Watch our story



Priority 3.2
Climate resilience
and biodiversity



Aims of Geest Adaptation: Groundwater modeling of measures in two focus areas

- Our pilot area is located in northern Lower Saxony, Germany (Fig. 1) and focuses on two main adaptation problems:

- groundwater salinisation at Minstedt waterworks**
- Minstedt waterworks is facing major problems with increasing chloride content in their extraction wells
- Aim:** Simulate how different Managed Aquifer Recharge (MAR) measures affect the fresh-saline groundwater interface (FSI) and test whether the interface can be pushed to greater depth to preserve freshwater resources for the public drinking water supply, especially with regard to climate change

Rewetting of the Gnarrenburger Moor

- The Gnarrenburger Moor (Gnarrenburg peatland) has been heavily drained due to former peat mining and is no longer in its natural state. In line with Germany's national peatland protection strategy, the area is determined to be rewetted to reduce CO₂ emissions
- Aim:** Model different drainage strategies to understand how the peatland water table and the groundwater table respond, and how these changes affect the Gnarrenburger Moor region

Achievements

Minstedt waterworks

- SkyTEM and semi-airborne electromagnetic (sAEM, LIAG) results were used for mapping the fresh-saline groundwater interface resulting in a salinisation map (Fig. 2)
- The Minstedt flow and transport model indicates the origin of the chloride and the reason for the increasing salinity in the extraction wells (Fig. 3)
- Model results show that freshwater infiltration into the aquifer and the relocation of extraction wells can help to push the fresh-saline groundwater interface away from the water catchment area
- Fruitful stakeholder discussions were held on possibilities for finding new well locations to avoid deterioration and on infiltration strategies

Gnarrenburger Moor

- Ground Penetrating Radar (GPR, LIAG) measurements improved the peatland structural model
- The model area was selected after discussion with the municipality of Gnarrenburg
- Groundwater model simulations show that the peatland water table can be controlled by the drainage system. In targeted areas the water table can rise, while it remains unchanged in other parts of the peatland (Fig. 4)

Challenges

Minstedt waterworks

- A relocation of wells would be very expensive and is limited to the water catchment area
- Water rights proceedings for changing the catchment area would take several years and during that time new regulations may come into force that complicate the process

Gnarrenburger Moor

- There is a major conflict of interest between the commitment of rewetting the peatland and actual agricultural land use and settlements
- Farmers would be willing to change their farming methods (e.g. paludiculture), but the financial hurdle is too great
- A national financial strategy for peatland rewetting is missing

Our strategy to foster a Blue Transition

Minstedt waterworks

- Our results are highly valuable for the Minstedt waterworks and indicate the origin of the chloride and which processes lead to the updoming of the fresh saline groundwater interface
- With an adapted pumping strategy – reduced pumping near the Oste river and targeted freshwater infiltration into the aquifer – the quality and quantity of usable groundwater can be preserved in the long term

Gnarrenburger Moor

- Our results show that a gradual rewetting of the Gnarrenburger Moor could be an effective measure for a stepwise restoration of the peatland as a CO₂ sink and reservoir
- Our stakeholder, the municipality of Gnarrenburg, plans to use our results to improve their dialogue with farmers and jointly develop strategies, as complete rewetting of peatlands means that conventional agricultural use of the land is no longer possible. Our results facilitate communication b
- Based on our results we developed a localised rewetting strategy, which can be implemented by the municipality of Gnarrenburg
- However, a rewetting strategy including a financial strategy on at least a county level is necessary to ensure ongoing rewetting, not only in the Gnarrenburger Moor, but also in other peatland areas in Lower Saxony. Without financial support from the state, very few land users are currently able to invest in adaptation measures. We will use our results to strengthen the understanding among landowners, and to help establish a supportive structure (financial, time schedule) on a countywide or nationwide scale

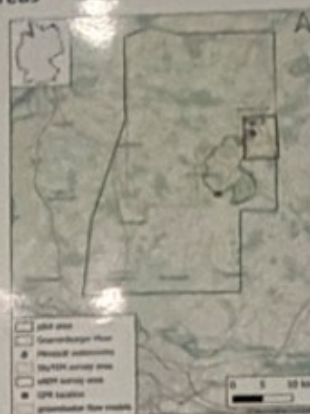


Fig. 1. The overview of the pilot area shows the location of the Gnarrenburger Moor (peatland), the location of the Minstedt waterworks, the Ground Penetrating Radar (GPR) measurement, the survey area of the SkyTEM and semi-airborne electromagnetic (sAEM) measurements, as well as the extent of the groundwater flow model.

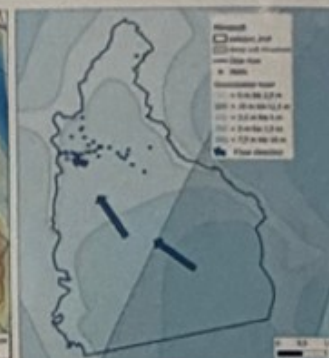
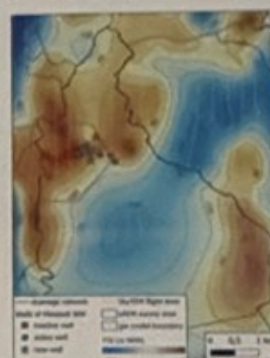


Fig. 2. Depth map of the fresh-saline groundwater interface (FSI) of the Minstedt waterworks (MW) based on groundwater composition data, including chloride, sulphate, and nitrate, and the regional semi-airborne electromagnetic (sAEM) data.

Fig. 3. Results from the Minstedt flow and transport model show the salinisation origin and which extraction wells are at risk.

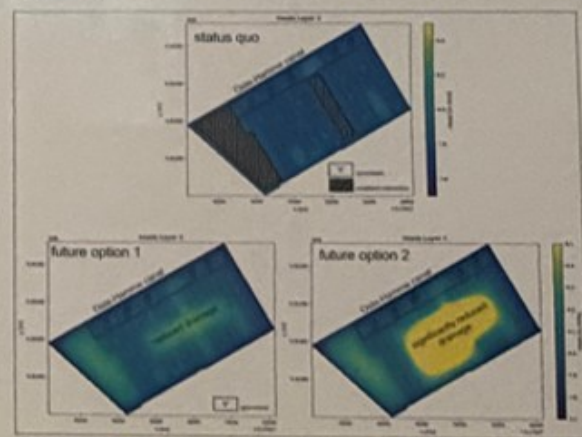


Fig. 4. Effects of different drainage strategies on the water table in the peatland. In targeted areas, the water table can rise, while in other parts of the peatland it remains unchanged.

GE 3: Humus

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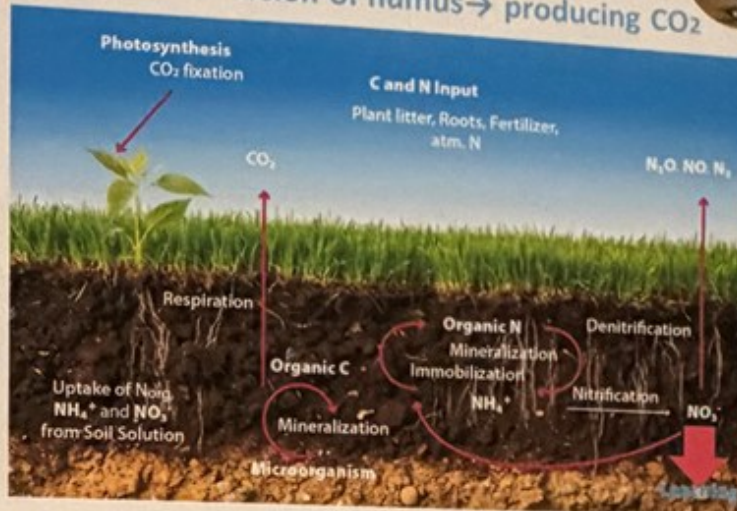
Humus oriented farm management to foster climate change adapted soil management in North-Western Germany

Humus content in soils is endangered by rising temperatures and changes in water balance in general

The consequences:

- increasing of nitrate leaching
- higher CO_2 emissions,
- higher irrigation demand
- loss of soil fertility and biodiversity,
- followed by decline in crop yields

Threat to conversion of humus → producing CO_2



Needs:

- Findings way for mitigation:
- Rising awareness for the impact of climate change on soil fertility and groundwater quality.
- Testing strategies in the field

& nitrate leaching to groundwater

Our strategy to foster a Blue Transition

The pilot combined field strip experiments (INGUS GmbH) with SVAT modelling by BGR using the agroecosystem model DAISY at three long term soil-observation sites. We sowed catch and cover crops to stimulate soil flora and fauna in the deeper horizon. Simulations compared scenarios with and without one-time deep ploughing (+5 cm) and included sensitivity analyses of soil properties and mineralization on parameters (BGR). We conducted numerical (SVAT) simulations and tested the sensitivity of carbon stock sequestration to tillage-induced changes in soil characteristics and layer-specific SOM turnover rates for two exemplary sites.

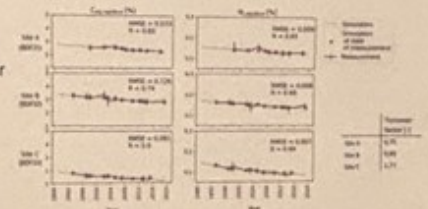
Achievements



Main modelling results:

Subsoil management can increase carbon storage potential, but results strongly depend on organic matter turnover processes in the additional soil layer.

- The simulations showed a high sensitivity to the mineralization turnover factor.
- Other investigated soil properties and hydraulic parameters had only minor effects.
- In the "worst-case" scenario (turnover rates comparable to topsoil across the full 35 cm), soil organic carbon decreased by about 4% within five years compared to the control



- There is an urgent need for long-term monitoring data to validate model predictions

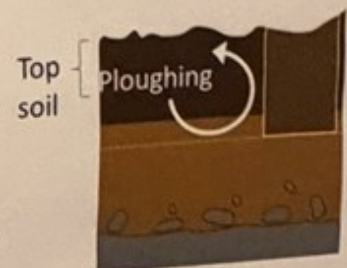
- In the "best-case" scenario, humus contents increased by up to 9%.
- Assuming a realistic turnover factor of 1, simulations indicated an increase in humus content of around 2% after five years

Challenges

The model analyses evaluate the potential and effects of different management adaptations to increase C stocks. The simulations also show potential threats to groundwater resources through nitrate leaching as a by-product of humus-increasing measures.

Uptake by stakeholders and future projects:

- Results can support evidence-based recommendations for climate-resilient soil management and water protection strategies.
- Findings are relevant for farmers, advisory services, water authorities and agricultural stakeholders interested in carbon farming approaches.
- The modelling framework can be transferred to other regions and management scenarios.
- Outcomes may feed into future research and policy projects on soil carbon sequestration, climate adaptation and sustainable agricultural land management.



Only once in a while.....

Securing the groundwater supply for field irrigation

Irrigated agriculture has been established in the region for over 60 years. More frequent droughts and higher temperatures, as well as lower rainfall during the growing season, increase the need for irrigation water. Since most of the irrigation water has so far come from groundwater, and groundwater abstraction has an impact on the regional ecosystem, management systems for groundwater abstraction must be designed and established in addition to the increasing use of groundwater substitutes.

General approach:

Adaptation by reorganizing groundwater abstraction to protect rivers and groundwater-dependent land ecosystems, balancing groundwater demand (nature and irrigation), identifying the effects of specific groundwater abstraction on small rivers.

Linking topics:

Cooperative groundwater abstraction management; Improvement of the ecological situation; Groundwater recharge and use of substitutes.

Our strategy to promote a Blue Transition

The WaterFarmers pilot project builds on an established groundwater monitoring system. An existing groundwater flow model was used to answer the following questions:
The identification of areas where the expansion of groundwater extraction, depending on the given climate change scenarios, has a negative impact on groundwater-dependent terrestrial ecosystems.
Identification of irrigation wells that are crucial for maintaining a balanced landscape water balance. As a result, we can make statements about the adaptation requirements to the well backdrop for field irrigation in the district of Uelzen and see which wells have to be laid where in order to be able to continue operating without having an impact on groundwater-dependent terrestrial ecosystems or flowing waters.

Report on the water rights proceedings

Within the framework of the licensing procedure under the Water Resources Act of the Federal Republic of Germany, the scope of the investigation was specified in order to meet the various requirements made by EU law, but which have also been and are made by local licensing authorities to comply with the prohibition of deterioration, but also to comply with the requirement for improvement. As part of the modelling, different states, spatial and temporal, must be compared in order to draw conclusions about the effects of increased groundwater abstraction in the future, for example. The following conditions must be observed:

New model variants and corresponding terms

1. Initial state:

Average weather and abstraction situation (reference period 2013 – 2022)

2. Prognosis Condition:

Average weather situation, withdrawals according to the requested quantity, reduced from around 70 million m³ to 65 million m³

3. Pre-Stress Condition

Average weather situation, withdrawals according to the reference period 2003 – 2007

4. Dry Weather Initial State

Dry weather situation, medium withdrawals (reference period 2013 – 2022)

5. Dry Weather Forecast Condition

Dry weather situation, overall average withdrawals according to the application volume

(1,000 % in 10 years, see Table 5-4):

1.25 times (5th year and 7th year) of the mean withdrawal according to the application quantity

Scenarios

The following scenarios emerge in the comparison:

Abbrev.	Scenario	Reference period (time series reference)	Relevance to specialist law
A1	Compliance with the prohibition of deterioration	Forecast minus baseline state (2013-2022)	Environmental compatibility (all relevant protected assets), aquatic and terrestrial habitat types, WFD, statutory landscape protection, special species protection, intervention regulation, national site protection
A2	Average of the growing season (April to September)	Forecast minus baseline state (2013-2022)	Environmental compatibility, terrestrial habitat types, species
A3	Average of the growing season (April to September)	Prognosis minus pre-load condition (2003-2007)	Natura 2000
A4	Monthly month of August (mean monthly outflow for August)	Prognosis minus pre-load condition (2003-2007)	Natura 2000 (only aquatic habitat types, species/habitats)
A5	Average of the growing season (April to September) in the second minimum year	Dry weather forecast minus dry weather baseline state (2013-2022)	Environmental compatibility, aquatic and terrestrial habitat types, species
B1	Compliance with the improvement requirement		
B1	Technical and substantive examination with regard to a threat to the (concrete) development goals of the Natura 2000 management plans	Note: only for habitat types/species in conservation status C	Natura 2000
B2	Technical and substantive examination with regard to a threat to the management objectives (management plan in accordance with § 83 WHG) and the programme of measures (§ 82 WHG)	Note: only for water bodies in not at least good status (surface water body: only ecological status, no chemical status, so basically unaffected by the project; Groundwater body: quantitative status and chemical status)	WFD

Achievements

In addition to identifying areas where the expansion of groundwater extraction has a negative impact on groundwater-dependent terrestrial ecosystems and rivers, irrigation wells were also identified that are crucial for the water balance of the landscape or that need to be relocated or adapted for future-proof abstraction.

In a general meeting, the goals and effects of the WaterFarmers project were explained to the farmers and a consensus on the distribution of the costs could be agreed with the farmers.

In addition to the general meeting with well over 300 participants, more than 10 meetings of the so-called steering group were held, 2 of them together with the responsible water authority.

Challenges

Since the scenarios to be examined were technically very extensive and there was an intensive need for coordination with the responsible state and local water authorities, the coordination process has already taken more than two years and has not yet been fully completed. Against this background, no local working groups have yet been held, so that the final fountain scenery has not yet been determined.



Figure 1: Association meeting to inform members of the umbrella organisation DFU



Figure 2: Project area showing water catchment areas and irrigation wells in the district of Uelzen

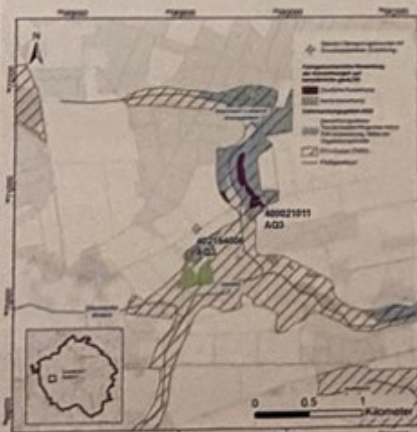


Figure 3: Influence of irrigation wells on groundwater-dependent terrestrial ecosystems



Figure 4: Ecological effect of the relocation of irrigation wells to groundwater-dependent terrestrial ecosystems

DK1: Climate-hydrological models for flood and contamination protection: Aabenraa city and town of Bylderup-Bov in Region of Southern Denmark

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Modelling tool for a better climate adaptation in urban area

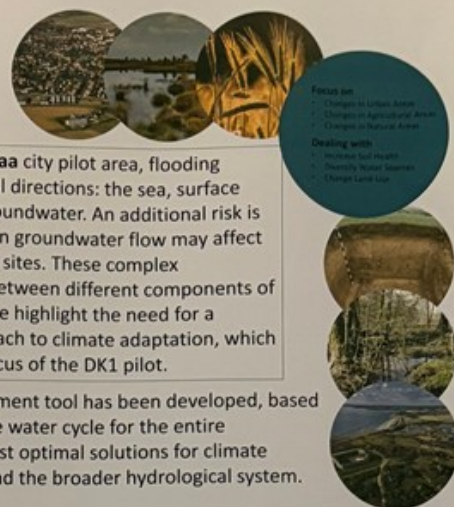
Climate change, including increased precipitation, flooding, and rising groundwater levels, affects the entire water cycle and poses significant challenges for urban areas. Within the DK1 pilot, two areas have been selected to illustrate different, but related, climate risks and management needs.



The pilot area **Bylderup-Bov** is particularly vulnerable due to its originally very high groundwater levels (approximately 30–40 cm below surface). Episodes of flooded basements and overloaded local sewage systems occur frequently, demonstrating how extreme groundwater conditions can put pressure on existing infrastructure.

In the **Aabenraa** city pilot area, flooding occurs from all directions: the sea, surface water, and groundwater. An additional risk is that changes in groundwater flow may affect contaminated sites. These complex interactions between different components of the water cycle highlight the need for a holistic approach to climate adaptation, which is the main focus of the DK1 pilot.

To support such an approach, an integrated water management tool has been developed, based on groundwater modelling that includes all elements of the water cycle for the entire catchment area. The aim is to identify and evaluate the most optimal solutions for climate adaptation, taking into account both local vulnerabilities and the broader hydrological system.



Our strategy to foster a Blue Transition

Linking underground knowledge to better climate adaptation decisions..

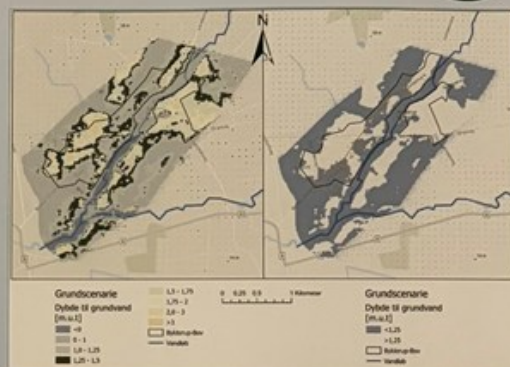
Why the Underground Matters

What happens underground has a major impact on groundwater, flooding and climate risks in our cities.



Our Holistic Approach in DK-1

- Improving knowledge of geology and groundwater
- Looking at the whole water cycle in the pilot area
- Including infrastructure and contaminated sites



Collaboration for Better Decisions

By combining data and expertise, we create a stronger basis for long-term climate adaptation and a sustainable Blue Transition.

Achievement

For the robust assessment of effects of climate change and climate adaptation measures, the detailed model of the underground in the water catchment has been required. In DK1, a holistic approach was applied, consisting of several measures aimed at improving knowledge about underground conditions in the pilot areas:

2. Geological modelling:
Focusing on the uppermost 50 m of the surface. Revealing a complex geology in both pilot areas.

Field work:
Seismic measurements
TEM measurements
Shallow boreholes with IoT sensors
Groundwater analysis

3. Groundwater models:
The transport paths for the groundwater based on the new geological condition together with a groundwater level from the IoT sensors and the existing data.

4. Climate-hydrological modelling:
The groundwater model incorporates three climate models that project increased precipitation over the next 75 years. Additionally, fourteen different scenarios were simulated, providing a robust understanding of the effects of potential solutions applied in the area.

The future application:
Dialog on the application possibilities in the future climate adaptation projects in urban areas within municipality. Sharing the results with other authorities.

Challenges

In Denmark, legislation is still divided, with different laws applying to the "same" water depending on where in the water cycle it occurs. This makes it complex to manage flooding coming from several directions.



- The latest legislation on groundwater management in urban areas does not include requirements for contamination management. This omission could result in significantly higher costs for climate adaptation projects
- Managing high groundwater levels in urban areas creates a need for sustainable and long-term solutions.
- There is a need for robust assessment of the consequences of climate change and climate adaptation measures in urban areas.
- Stakeholders, such as the local water utility company, lack sufficient funds to implement the proposed solution from Blue Transition



DK2: Meadow Aastrup Kær

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Multifunctional land use and carbon sinks in peat soils

The DK2 Meadow Aastrup Kær pilot examined how rewetting of drained peat soils may reduce greenhouse gas emissions. Peatlands in Denmark are typically low-lying agricultural areas that have been drained, making them susceptible to greenhouse gas emissions. Rewetting these areas has the potential to lower emissions, create buffer zones for increasing precipitation, and to increase the natural value, but current knowledge about the actual impact on emissions remains limited. Aastrup Kær was selected because it forms part of the national rewetting initiative, allowing project results to be directly shared with the National Nature Agency.

Our goals were to:

- 1) Assess legislative and governance challenges that influence rewetting efforts,
- 2) Improve mapping of peat soils with geophysical methods, and
- 3) Provide a baseline of CO₂ and water table depth measurements related to environmental parameters prior to rewetting.

Our strategy to foster a Blue Transition

- Reducing barriers to the blue transition requires action on several fronts: **streamlining dispensation procedures** in nature-protected areas to ease the documentation burden on local authorities; **aligning the parallel national rewetting schemes** so landowners and municipalities can navigate a single, coherent pathway; and **strengthening the resources and expertise available at the municipal level**, particularly in smaller rural municipalities where most rewetting takes place.
- A further strategic lever lies in the **design of participation incentives**. The Green Tripartite Agreement combines voluntary landowner participation with structural pressure — most notably the CO₂ levy on lowland soils set to take effect in 2028, estimated at 1,200–2,000 DKK per hectare annually for those who do not convert their land. This hybrid of soft and hard governance instruments is intended to accelerate uptake without resorting to direct mandates, but its success depends on landowners experiencing the voluntary track as genuinely workable. If documentation burdens, scheme misalignment, and limited municipal capacity make the "voluntary" pathway slow or uncertain, the structural pressure risks being perceived as coercion rather than incentive — undermining legitimacy and the long-term cooperation that land-use transitions require.

Achievement

- A governance screening of the legal and institutional frameworks showed that EU and Danish legislation designed to protect nature, and biodiversity can pose significant barriers to rewetting efforts. Dispensations are possible but constrained, and local authorities often struggle with the high documentation demands in nature-protected areas due to limited resources and specialized expertise at the municipal level.
- We mapped the geological layers of Aastrup Kær using several geophysical methods. By integrating the geophysical models with borehole data, we determined the thickness and spatial distribution of the peat.
- We compiled a technical note with recommendations on the most suitable geophysical methods for mapping peat thickness and distribution.
- We analyzed data series of CO₂ and water table depth in Aastrup Kær using machine learning. We found that water table depths and CO₂ concentrations at 1 m above ground are predictable up to 1 and 6 days into the future, respectively, based on environmental variables. However, discrepancies remain significant.

Challenges

The governance screening identified three interlocking governance challenges. First, **regulatory complexity**: legal frameworks such as the EU Habitats Directive, Natura 2000, and the Danish Nature Protection Act (notably §3 and §29a) restrict land-use changes to safeguard biodiversity, and although dispensations can be sought, the documentation requirements are substantial, and case processing is lengthy. Second, **institutional fragmentation**: the Green Tripartite Agreement and the two parallel rewetting schemes (Klima-Lavbundsordningen and Vand- og Klimaprojekter) involve overlapping mandates and differing project-ownership rules, making it difficult for landowners and municipalities to identify clear decision pathways. Third, **capacity asymmetries**: administrative responsibility is decentralized to municipalities while expertise and resources remain concentrated at the national level, placing disproportionate pressure on smaller rural municipalities and risking uneven implementation across the country.



Field mapping with students in Aastrup Kær, AU Summer school.

- Prolonged periods of heavy precipitation caused extensive flooding across parts of the meadow, preventing geophysical surveys from being conducted in these areas. Consequently, the investigation was focused on the southwestern section of the meadow.
- The low-cost CO₂ and water table depth measurements performed in this study were inadequate to constrain CO₂ fluxes from the meadow and relate it to water table depth. Future instrumentation upgrades are necessary to achieve solid measurements of CO₂ (and CH₄) fluxes and assess the impact of rewetting.



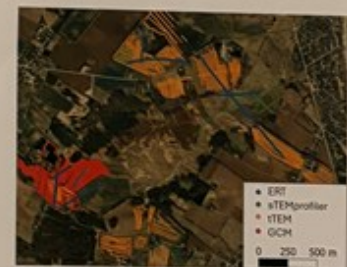
Data logger for CO₂ and water table depth monitoring.



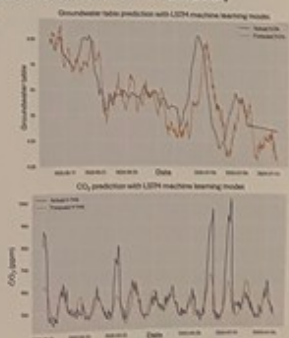
Aastrup Kær in Winter 2024



Geophysical field investigation.



Geophysical mapping in Aastrup Kær



Future scarcity of fresh and clean groundwater under a changing climate

The island of Endelave is transitioning from farming to eco-tourism, straining its limited groundwater resources. Climate change, with rising sea levels, storm floods, and seasonal droughts further threatens these resources by increasing the risk of saltwater intrusion. This pilot project examines the socio-economic impacts on groundwater, including effects on the island's economy, population, and water consumption. It leverages comprehensive geophysical and hydrogeological data to develop a groundwater model, simulating future climate scenarios and informing local authorities and utilities. The model aids decision-making for land use transition and ecosystem service management.

Goal: Comprehensive evaluation & socio-economic assessment of the future groundwater resources

Challenges:

1. Climate changes (rising sea level, storm floods, and seasonal droughts)
2. (Legacy) Pollution from agriculture.
3. Water consumption patterns and tourism.

Our strategy to foster a Blue Transition

The most immediate risk of groundwater contamination from agricultural production on Endelave is reduced through recent land-use change around the waterwork infiltration area. For the future, the infiltration zone should be re-evaluated to see if the protection zone is large enough, and the groundwater quality monitored to see if legacy pollution reaches the abstraction wells.

To mitigate the risk of saltwater intrusion, reducing summertime groundwater abstraction should be considered, potentially capping the number of summertime tourists and/or implementing water saving measures.

Despite mitigation measures, it may be necessary in the future to abandon the current groundwater wells. One potential option for an alternative groundwater source is by investigating deeper aquifers within the buried valleys on the island. The geophysical data collected in this pilot provide an excellent basis for selecting drill sites for further investigation of this option.

Achievement

- **Geophysical mapping:** rigorous geophysical mapping of the island and shallow subsea regions. The investigation revealed two up to 100-meter-deep potential aquifers. The current abstraction is in a 20 m deep aquifer.
- **Groundwater monitoring:** establishment of 14 monitoring boreholes with 3 years of water pressure data.
- **Geological- and hydrogeological modelling:** development of new geological and hydrogeological models for Endelave based on geophysical and groundwater monitoring data.
- **Socio-economic screening:** assessing how changes in land use and tourism can influence groundwater resources and the long-term availability of groundwater on the island through different scenarios.
- **Governance barrier analysis:** identifying and examining legislative, administrative, and organizational factors that could potentially constrain the implementation of climate change adaptation initiatives on Endelave.
- **Integrated assessment of societal, environmental, and climatic drivers:** focusing on how these interrelated factors may affect future groundwater supply. This assessment is informed by findings from the Blue Transition project and supplemented by empirical studies.
- **Augmented Reality (AR) application** developed as a visual support tool.

Challenges

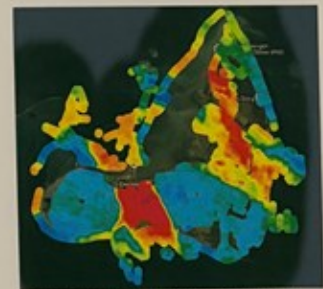
- Securing a framework for continued monitoring of groundwater pressure and salinisation
- Further investigation of alternative water supply from deeper aquifers on the island



Climate scenarios for Endelave predict coastal erosion and increased flooding risk.



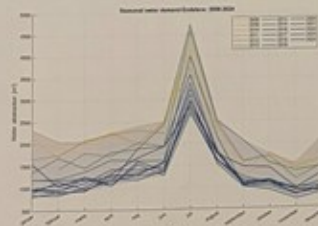
FloatEM investigation setup for resistivity mapping of the shallow sea around Endelave.



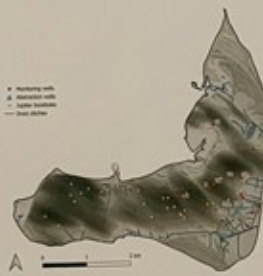
Geophysical mapping onshore and offshore Endelave reveal buried valleys (red).



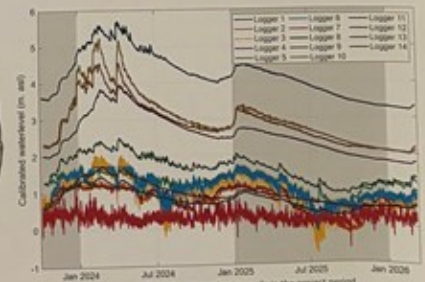
Augmented reality application developed as a visual support tool



Seasonal peak in water abstraction at Endelave coincides with the tourist season (July)



Location of monitoring wells established as part of Blue Transition



Groundwater heads from the 14 monitoring wells in the project period

FR1 : Guidel: From Water Supply to Water Resilience, supporting Informed Decisions for People and Nature

BlueTransition
How to make my region
climate resilient

Interreg
North Sea
Blue Transition

How to secure drinking water supply while preserving ecosystems in a context of climate change, population growth, and increasing summer droughts?

Located in Lorient Agglomération, the pilot focuses on a planned drinking water abstraction upstream of a Natura 2000 protected wetland system that depends on groundwater inflows. The objective goes beyond technical water management: it aims to rethink water governance by considering water as a shared commons, supporting both human activities and non-human living systems.

Climate change is intensifying pressures on water systems and amplifying interdependencies between land use, groundwater, surface waters, and ecosystems. Decisions taken today—particularly regarding land management and groundwater abstraction—will shape long-term territorial resilience under climatic conditions that have no historical equivalent.

The Guidel pilot aims to provide decision-makers with robust, shared, and forward-looking knowledge to support balanced and anticipatory choices.

Challenges :

- Thinking the future together and prepare regulatory planning documents based on scientific results
- Grow citizen concern



Lannemeur N2000 protected ecosystems @ABCZone

Achievements to foster a Blue Transition

System understanding and science-based dialogue between sectors and interests

- Anticipation through prospective modelling: a wide range of land-use and water-management strategies have been explored, helping identify the most robust options before crises occur.
- Scientific results and prospective scenarios directly informed a cross-sector Water Resilience Plan (regulatory document) co-developed with Lorient Agglomération

Short term technical measures

- Identify critical zones where monitoring efforts should be prioritised to inform decisions
- Define a minimum ecological groundwater discharge feeding protected ecosystems

Long-term transition

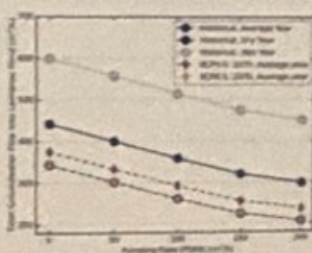
- Opportunity of adaptive pumping strategies, adjusted to seasonal and climatic conditions, can substantially limit negative impacts and offer concrete options for balancing human and ecosystem needs.

Sharing habitability issues & raising concern

- Support local knowledge sharing with citizens using a smartphone-based nitrate measurement tool to show that (all) humans and ecosystems are connected. Measuring together on the field allows to foster dialogue across diverse perspectives and making invisible water tangible.
- Curiosity and a sense of wonder prevails, a nature experience provide a beneficial effects.



Reduction in groundwater flows feeding rivers and wetlands as a result of pumping



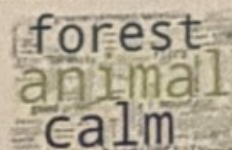
The compromise curves defining the water share between humans and ecosystems



The Open Observatory: a meeting point between researchers, citizens and public stakeholders @ Hubert Raguet

Challenges

- Political and institutional instability, and economical constraints slow the implementation of long-term adaptive strategies, despite strong local engagement.
- Water governance remains fragmented, with limited transversal coordination across sectors (water supply, land use planning, agriculture, environment), making it difficult to address systemic water challenges.
- Engineering consultancies to address specific identified issues remains the prevailing approach.
- The complexity of subsurface processes requires continuous efforts to translate scientific knowledge into actionable policy tools.



Word cloud of feelings expressed by high school students after a technical mediation workshop on ecology

Perspectives

- The Open Observatory, a shared framework where scientific knowledge and empirical data are jointly mobilised, enabling place-based research, long-term monitoring, and collective learning across territories.
- Emergence and discussion of new concepts : Territorial carrying capacity
- New emerging collaboration on the management of inherited landfills