ISSUE 03 . . . . . . APRIL 2010

Salt water intrusion in coastal aquifers

by Luc Lebbe and Gualbert Oude Essink

In the CLIWAT project, we determine the physical impacts of climate change on groundwater and surface water systems in a part of the North Sea region. In this newsletter, we focus on the topic of salt water intrusion. Tools and methods are presented that are used in the research to increase our knowledge of the present physical system in the coastal water system (via monitoring) and to assess the future changes (via modelling).

The Phenomenon of Salt Water Intrusion

Fresh groundwater resources in many coastal regions in the world, especially low-lying deltaic areas, are used intensively for domestic, agricultural and industrial purposes. The availability of huge quantities and the high quality of this fresh groundwater relative to the surface water makes it a popular resource. In the future, the exploitation of fresh groundwater resources will increase due to population and economic growth, intensified agricultural development, and the loss of surface water resources due to contamination. In addition, the anticipated sea level rise and changes in recharge and evapotranspiration patterns will exacerbate the pressures on the coastal groundwater system. Many aquifers in low-lying deltaic areas already experience an intensive salt water intrusion as well as the upconing of saline groundwater from old marine deposits due to natural and anthropogenic causes (Figure 1 and 2, p.2). Salinisation of the aquifers can lead to a severe deterioration of the quality of existing fresh groundwater resources. In addition, human interferences, such as mining of natural resources (water, sand, oil and gas) and land reclamation (causing subsidence) threaten coastal lowlands even more. **(cont'd./. . . p.2)**

Editorial

Since the October 2009 newsletter, the CLIWAT group has been working hard in the seven pilot areas, collecting data for the groundwater models. The extensive field work was carried out with a wide array of equipment, and included many ground-based and airborne surveys. In addition to obtaining significant and informative data sets the field work increasingly receives media coverage. Especially the airborne surveys have attracted a lot of attention. This has resulted in more than 50 newspaper articles, radio spots and TV coverage for the CLIWAT project during the last year. The UN Climate Change Conference in December 2009 did not result in binding CO2 emission targets. Nevertheless, a process towards binding targets was started, but the rates of reduction are lower than those already recommended by the Intergovernmental Panel on Climate Change (IPCC). This means that communities in the North Sea region are facing higher temperatures, a greater rise in sea level and more pronounced changes in precipitation patterns than was first estimated. These climatic changes will undoubtedly affect groundwater systems. In order to prepare for these inevitable changes, and to determine useful and necessary protection measures, it is essential that the adaptation process is based on sound knowledge derived from verifiable scientific research. In general, most countries have an idea of what to expect when dealing with temperature increases, changing precipitation and sea level rises. But when it comes to changes in groundwater dynamics and how to deal with the related changes, there is far greater ignorance. CLIWAT will employ groundwater models, and present strategies to deal with the consequences of changes in groundwater systems. Communities need to know which climate scenarios are most probable, so that they can plan for their environmental systems including groundwater. While southern parts of Europe are facing a lack of groundwater in the future, the major problem for the North Sea region will be how to deal with increasing groundwater levels, and how to protect groundwater. In this third newsletter, the hot topic is salt water intrusion. Especially on the coastal islands of the North Sea this is increasingly becoming an important issue. Furthermore, interesting articles about field work and water supply are presented. Last but not least, upcoming relevant events are indicated in the calendar. We hope you will find the newsletter worth reading. Feel free to comment and post questions on our web site, www.cliwat.org. This is also the place where you can subscribe to the newsletter, view our new GIS solutions and see results from the pilot studies.

Kind regards

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The Interreg IVB North Sea Region Programme
Investing in the future by working together for a sustainable and competitive region

About CLIWAT: Adaptive and sustainable water management and protection of society and nature in an extreme climate

The project will focus on the effects of climate change on groundwater systems. CLIWAT aims to identify the challenges caused by the higher water levels, and to develop climate scenarios focusing on surface water and water supply as well as the impacts on buildings. The quality changes of the groundwater resource caused by salinisation, outwash from point sources and new demands for irrigation are some of the issues which will be investigated. This will enable the North Sea Region to react more efficiently to the consequences of climate change. The project will build on and improve existing geophysical and geochemical methods; these will be tested in the partner regions in order to be able to develop ground water models and furthermore recommendations for the North Sea Region on how to deal with the consequences of increased groundwater levels.

(Continued from p.1)

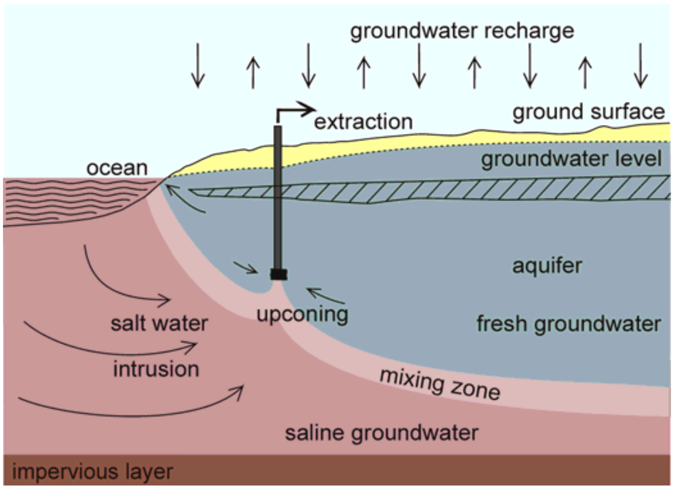

***Figure 1**: Salt water intrusion and upconing of saline groundwater in the coastal zone*

Consequently, salinities of surface water systems increase and land degradation due to salt damage may occur as soils become more saline.

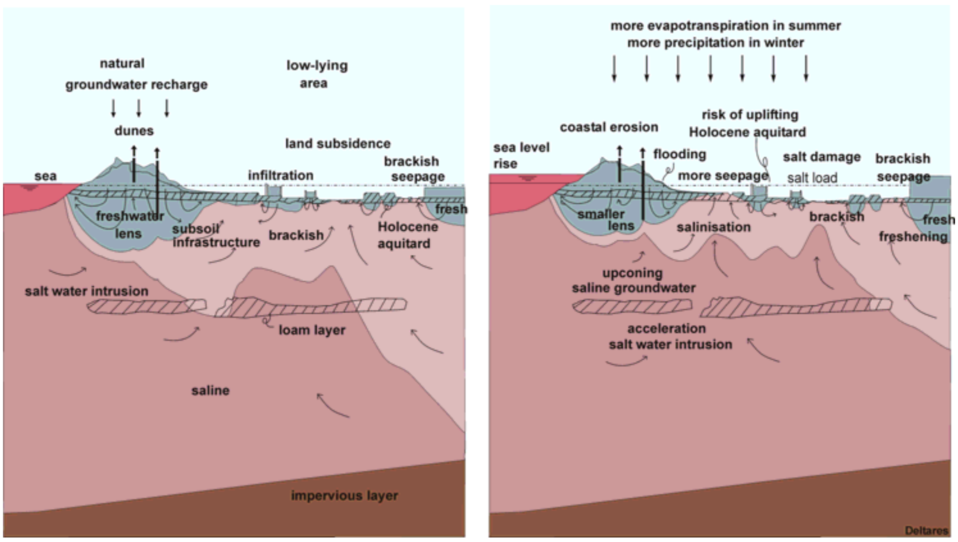

***Figure 2**: Conceptualisation of the (a) present and (b) future groundwater system in a low-lying deltaic area*

Tools and methods: monitoring and modelling

We strongly believe that by combining various kinds of tools and methods, the relevant subsurface processes in the coastal zone can be better understood. In addition, sophisticated numerical modelling tools make the prediction of the future state of water system more reliable. In CLIWAT, we are able to merge common existing techniques with new innovative methods such as SkyTEM/HEM data (in a later newsletter). Especially in the determination of the fresh-brackish saline distributions in the groundwater system, various techniques are combined, such as groundwater samples, geo-electrical borehole logs, electrical CPT, VES, EM31, EM34,groundwater extractions, CVES and TEC probe data. In this newsletter we discuss two techniques: 1) geophysical borehole measurements, and 2) numerical modelling of variable density groundwater flow and coupled salt transport (we use the code MOCDENS3D, which is similar to SEAWAT).

Geophysical borehole measurements

As basic data for the modelling of salt water intrusion two kinds of geophysical borehole measurements are very important: 1) the electrical conductivity of the sediments and, 2) natural gamma radiation of the sediments. One of the most interesting methods to measure the electrical conductivity is the focused electromagnetic induction log in an observation well with a short screen at maximum survey depth This allows the measurement of electrical conductivity of the sediments versus depth and the collection of pore water of the sediments at the depth of the well screen of which electric conductivity can be measured. First of all the electrical conductivity of the sediments contains information about the electrical conductivity of the pore water and in a lesser extend information about the porosity and the electrical conductivity of the matrix. The natural gamma radiation contains primarily information about the clay content and to a lesser extent information about the porosity. The porosity and/or the formation factor are also a function of the pore water conductivity. By a joint interpretation of the induction log, the natural gamma log and the observed pore water conductivities one can be deduced the variation of the pore water electrical conductivity versus depth and made an estimation of the variation of the porosity and of the hydraulic conductivity versus the depth.

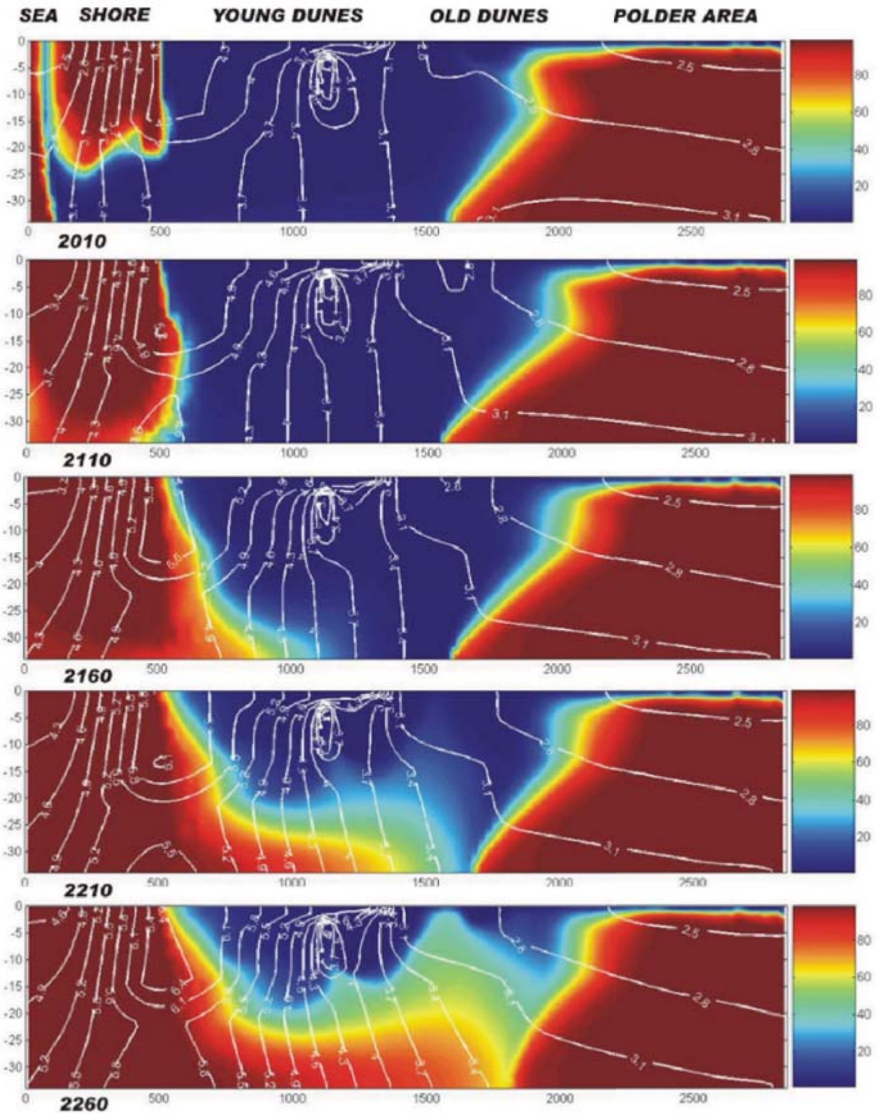

***Figure 3**: Simulated evolution of the fresh-salt water distribution in north-south cross-section near the village of De Haan. Colours represents the salt water percentage (0% is fresh water (blue colour) with TDS = 500 mg/l, 100% is salt water (red colour) with TDS = 28 g/l). White contour lines are fresh water heads in mTAW (Belgium national reference level). On vertical axis level in mTAW and horizontal axis is distance in m.*

Case in Middenkust, Belgium

To simulate the impact of sea level rise on the withdrawal of fresh groundwater in the Belgian coastal plane a special approach was chosen. The model program interface (SWI-FLEC3D) was developed which allows the generation of the input files for the MOCDENS3D code with a minimum number of input data. These data are generated using the hydrogeological data base of the Belgian coastal plain. This approach allows to simulate the fresh-salt water flow in detail in a selected area. This selected area can even be a cross section as will be demonstrated here. This cross section is perpendicular to the Belgian coastline, and is located near the village of De Haan and runs approximately in the N-S direction. The northern boundary is situated under the sea bed/level about 100 m north of the low-low water line (Figure 3). Southbound the cross section traverses consecutively the shore, the recent dunes, the old dunes and the polder area. The three-dimensional finite difference grid consists of 114 rows, 3 columns and 34 layers. All model cells of the finite difference grid have the same squared surface with a side of 25 m. All layers have the same thickness of 1 m. In the middle of the modelled dune area ground water (51% of the recharge on the young and old dunes) is withdrawn. In the simulation period of 250 year the sea level rises with a velocity of 0.9 m/century. As a consequence the freshwater head of the uppermost model cells under the shore and at the vertical boundary under the North Sea rises with 0.09 m per decade. The water table in the polder area is controlled by the same traditional drainage system so that the fresh water head at uppermost model cells under the polder area and under the southern vertical boundary are unaltered during the simulation period. In Figure 3 the simulated evolution of the fresh-saltwater distribution is shown.

Case in The Netherlands, the whole coastal zone

In collaboration with the Dutch Hydrological Modelling Instrument (NHI) Programme, a 3D numerical model of the entire groundwater system in the Dutch low-lying coastal zone, where fresh-brackish-saline groundwater is present next to each other, has been constructed for CLIWAT. National databases on topography, geology (REGIS), chloride concentration (combining VES, borehole measurements and analyses with the brackish-saline interface within the ZZREGIS database, Figure 4a) and geo-hydrology (extraction rates) and hydrology (precipitation, evapotranspiration, drainage and water channels characteristics) are consulted to set up a 3D model to simulate variable-density groundwater flow and coupled salt transport. The model consists of 20.6 million active model cells of 250 by 250m^2 and will be used in the CLIWAT project to simulate the impacts of sea level rise, land subsidence, climate change (changes in groundwater recharge over seasons), and if applicable human compensating measures on the Dutch fresh groundwater resources. At this point in time, some preliminary results are shown to give an impression of the possible output of the model (Figure 4b and 5). Figure 4b displays that the zone of influence is surprisingly limited to areas within 10 km of the coastline and the main rivers. This is because the increased hydraulic head in the first aquifer near the coast can easily be released through the highly perforated Holocene confining layer.

Conclusions

By combining various tools and methods on monitoring and modelling, our knowledge about the most relevant processes on flow and transport processes in the groundwater system in coastal zone on both local and regional scales will be improved significantly in the CLIWAT project.

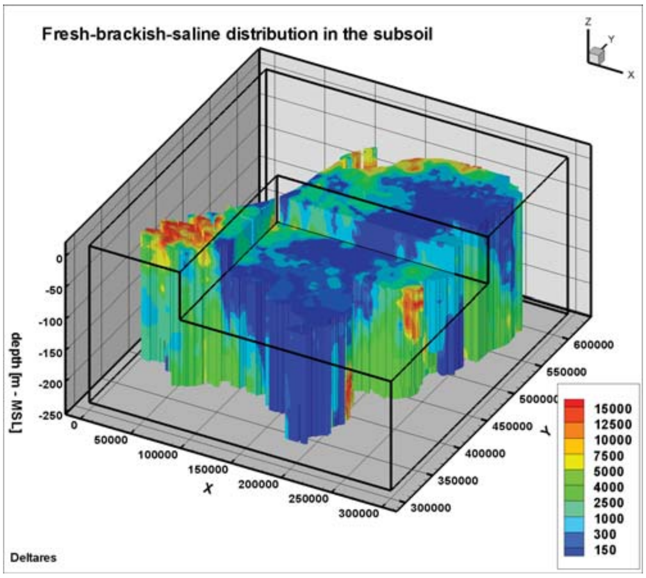

***Figure 4a**: 3D chloride distribution in the Netherlands,based on monitoring results and interpolation techniques*

In addition, the numerical models, developed with this new knowledge, will improve the reliability of numerical results on future changes in coastal groundwater systems. Based on these simulations, no-regret adaptation or mitigation measures can be implemented in time to secure fresh water resources in the coastal zone in a changing world.

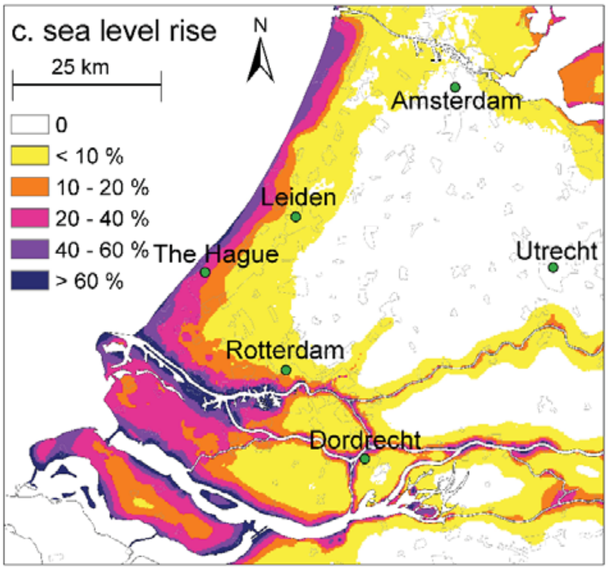

***Figure 4b**: Modelled increase of hydraulic heads in the first aquifer in a part of the Dutch coastal zone caused by sea level rise, expressed in percentage of absolute sea level rise*

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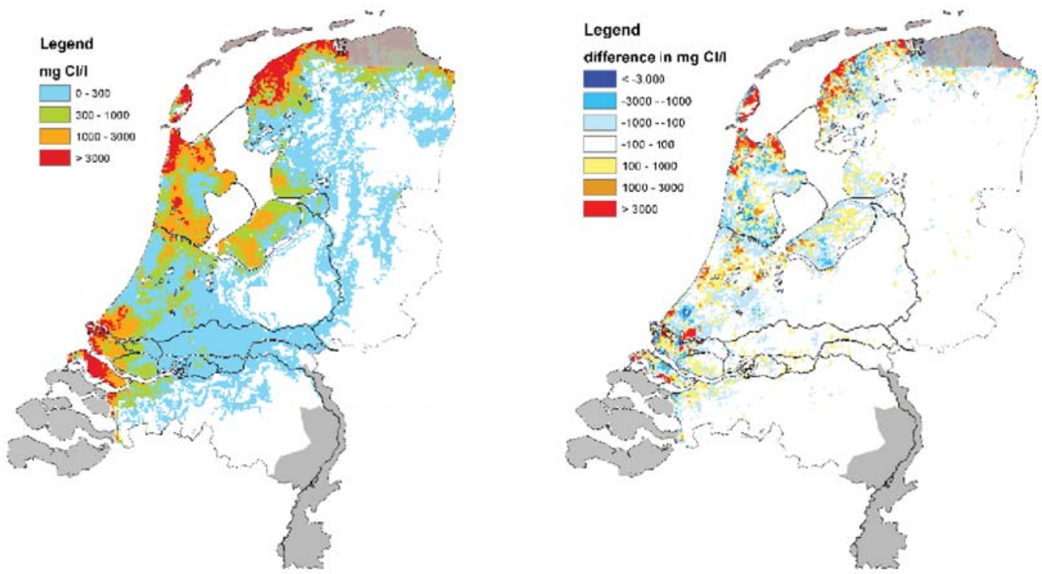

***Figure 5**: a) Present chloride concentration at the bottom of the Holocene aquifer; b) Difference in chloride concentration at the bottom Holocene aquifer, viz. situation at 2100 for climate scenario W+ (dry climate scenario plus 85 cm sea level rise, 2100) minus present situation at 2000: red means salinisation of groundwater system, blue means freshening*

Modelling climate change in the Egebjerg area, Denmark: What are we going to do?

by Klaus Petersen

Current knowledge about how subsurface waters and especially groundwater will respond to climate change and climate change-driven variability is very limited. Furthermore, many groundwater systems have been distorted by human activities not necessarily related to climate change. Consequently, there is an urgent and ongoing need to deal with the expected impact of climate change and its consequences.

The impact of climate change on specific water resources (and water supply) is closely related to local geography (geological and hydrological). The Danish Meteorological Institute's (DMI) predictions for the Danish climate indicate stressed groundwater resources. Additionally, a Danish regional study conducted by van Roosmalen et al (2007), showed that, with regards to IPCC climate change scenarios, geological factors are vital in determining the outcome (model predictions) on both groundwater as well as surface water systems. Highly consistent and detailed geo models are therefore essential when dealing with any hydro-geological climate change scenario.

Overall challenges facing water resources management:

- Increased flood risk in river basins, along coastal zones, and "groundwater-flooding"
- Decreased water availability – during summer season
- Deteriorated water quality (including saltwater intrusion)

Fieldwork and model work in Egebjerg pilot area F will incorporate these challenges, as will the CLIWAT project, providing a lot of new knowledge on these issues.

The Egebjerg area

The Egebjerg area is situated in eastern Jutland, near the city of Horsens. The model area is approximately 200 km^2, and its central part (90 km^2) is the main focus of CLIWAT (see Figure 1). Land use is mainly agriculture with a few villages. The area supplies Horsens and surrounding villages with groundwater from wells located in aquifers 20–140 m below the surface. Aquifers are located in two or three levels, protected by thick layers of clay tills/clays. Buried valleys dominate the subsurface geology, and complicate the interpretation of groundwater flow and its interaction with surface water. In general, the groundwater quality is good though there are major problems with naturally occurring arsenic. However, most of the waterworks are able to deal with the arsenic problem using simple water treatment. Waterworks abstract approximately 3.5 mil. m^3 of water per year in the central Egebjerg area. The maximum permitted amount of groundwater that can be abstracted is 6.5 mil. m^3 per year.

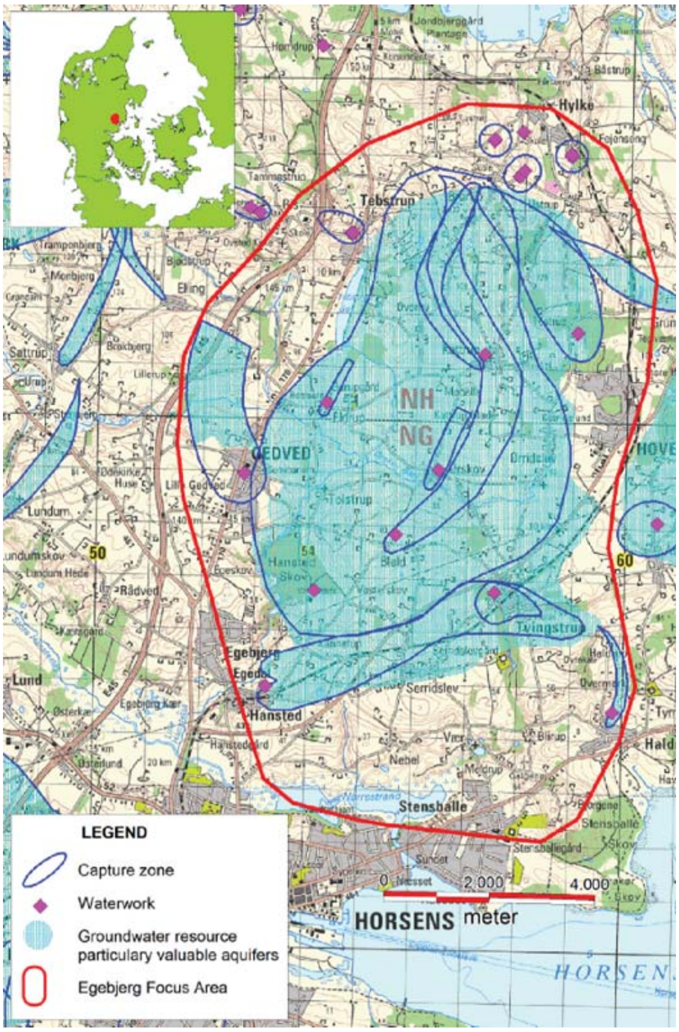

***Figure 1**: Map of Egebjerg area showing groundwater resources*

A vulnerable resource

Previous studies indicate a limited groundwater resource and a level of water abstraction that is just in balance with the amount of abstracted groundwater (3.5 mil. m^3 per year). Climate change impact is expected to adversely affect this balance and decrease the potential water supply. In addition, the waterworks may well use the entire permissible amount (6.5 mil. m^3 per year), which will almost certainly result in problems of severe over-exploitation. Waterworks (administrated by the municipality of Horsens) abstract vital amounts of groundwater in Egebjerg, and supply domestic water to Horsens and the nearby villages. The groundwater resources in Egebjerg must be protected to meet the current and future demands for domestic water. The need to adapt to the predicted climate changes is urgent, and the Egebjerg project as well as the CLIWAT project in general will provide the basis on which adaptations can be made. **(cont'd./... p.8)**

CLIWAT press coverage

by Rolf Johnsen and Jörg Krywkow

The centrefold of the 3rd issue displays five out of more than fifty local and regional press articles during the last twelve months. These five news clippings illustrate how CLIWAT activities are perceived and discussed in The Netherlands, Denmark and Germany.

① *Airborne measurement of saline groundwater*, in: **De Sjouw, 04/09/2009**. Our colleague Arjen Kok of Vitens introduces the reader to airborn survey approaches in order to explore sustainable and self-sufficient groundwater uptake for the island of Terschelling in the Dutch Wadden Sea.

② *Ground measurements with a helicopter*, in: **De Terschellinger, 24/09/2009**. The article covers the same issue as the previous article.

③ *Detecting groundwater with a Ground Penetrating Radar (GPR)*, in: **Der Inselbote, 17/07/2009**. In this newspaper GPR activities on the island of Föhr (North Friesian coast) are described. The two students in the picture intent to detect groundwater flow directions.

④ *Geologists keep a good eye on groundwater*, in: **Horsens Folkeblad, 05/08/2009**. This article covers CLIWAT activities in the town of Horsens. The mean surface water level in Horsens is expected to raise between 0,5 and 1,5 metres in 2070. This is due to increasing groundwater as well as sea levels. Within the project a large number of drillings and water samples has been executed.

⑤ *Climate change and groundwater*, in: **Der Inselbote, 25/06/2009**. Local residents are concerned about the exploration of potential underground CO_2 disposal sites. The article assures the reader that the seismic measurements are not related to CO_2 grouting but examine the impact of climate change on groundwater dynamics.

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Op weg naar duurzame zelfstandige waterwinning op Terschelling:

Meten naar zout grondwater vanuit de lucht

Als er één tak van wetenschap is die met beide benen op de grond staat, zou je verwachten, dan is dat wel de geohydrologie: het vakgebied dat zich bezig houdt met bestudering van het grondwater. Maar schijn bedriegt. Met de allernieuwste technieken wordt nu ook vanuit de lucht geohydrologisch onderzoek verricht. Dat biedt tal van nieuwe perspectieven en mogelijkheden.

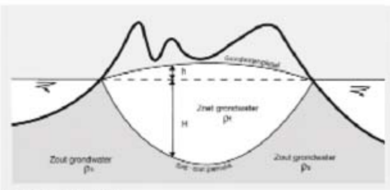
En dat is maar goed ook, want de uitdagingen waar de waterbeheerders en het drinkwaterbedrijf voor staan zijn groot. Ga er maar aan staan: de bodem daalt in grote delen van de provincie Fryslân, het klimaat verandert en de zeespiegel stijgt. Dan is het verdraaid lastig om alle watergebruikers te voorzien van voldoende water van voldoende kwaliteit. Daarnaast is Vitens bezig met een studie om te kijken of een duurzame zelfstandige waterwinning op het eiland in de toekomst mogelijk is, zonder drinkwater aanvoer vanaf de vaste wal. Een bijzonder onderzoek helpt Vitens om meer inzicht te krijgen in de mogelijkheden.

Van 14 tot 18 september 2009 zal een helikopter af en aan vliegen in noord Fryslân en op Terschelling. Het betreft een meetcampagne in het kader van het Cliwat project. Dit is een groot Europees project waar voor Fryslân het Wetterskip, Vitens en Provincie Fryslân bij betrokken zijn. Andere betrokkenen zijn onderzoeksinstituut Deltares uit Utrecht en Deense en Duitse onderzoekers. In het Cliwat project worden de effecten van klimaatverandering op de waterhuishouding en met name het evenwicht tussen zoet en zout grondwater onderzocht.

Zoet water op een eiland omringd door de zoute zee
Terschelling wordt omringd door zout zeewater. Voor de drinkwatervoorziening wordt gebruik gemaakt van zoet grondwater, opgepompt uit de duinen ten noorden van West Terschelling. Hoe kan het dat er een grote hoeveelheid zoet water op het eiland aanwezig is, ondanks dat het omgeven wordt door zout zeewater?
Op de Waddeneilanden is sprake van een overschot aan neerslagwater. Er valt meer regen dan er verdampt. Een deel daarvan wordt via sloten afgevoerd uit het duin of de polder om uiteindelijk te worden geloosd op de Waddenzee. Het resterende gedeelte infiltreert in de bodem. Dit water komt ten goede aan de voorraad grondwater.
Door het verschil in soortelijk gewicht tussen zoet water (1000 kg/m3) en zout water (1025kg/m3) drijft het zoete (grond)water op het zoute (grond)water. Net als olie, dat door het verschil in soortelijk gewicht, ook drijft op water. In de bodem heerst een hydrostatisch evenwicht, waardoor het zoete en zoute water niet mengen.
Wanneer duinen hoog genoeg zijn of verschillende duinen achterelkaar een breed duincomplex vormen, kan de grondwaterstand zich verheffen, ook wel opbollen genoemd, tot boven het gemiddelde zeeniveau.
Op Terschelling worden grondwaterstanden in het duin aangetroffen van boven de 5 meter boven NAP of zeeniveau. Deze hoge grondwaterstand veroorzaakt een neerwaartse druk, die in staat is de grens tussen het zoete en het zoute grondwater weg te drukken. Rekeninghoudende met dit evenwichtsprincipe zou 1 meter opbolling van de grondwaterstand een diepte van het zoet-zout grensvlak tot gevolg hebben van 40 meter, 2 meter opbolling 80 meter, enzovoort. Deze theorie over de verdeling van zoet en zout water in de ondergrond werd 'ontdekt' door de Nederlander Badon Ghijben in 1888 en de Duitser Herzberg in 1901. Sindsdien staan het bekend als het Ghijben-Herzberg principe.


Helicopter met meetapparatuur


Vlieggebied SkyTEM



Ghijben-Herzberg principe

Zoetwaterbel op Terschelling
De zoetwatervoorraad onder het eiland die volgens het Ghijben-Herzberg principe is gevormd, wordt ook wel zoetwaterbel genoemd. De diepte ervan varieert. Op Terschelling is de zoetwaterbel het diepst onder de bossen nabij West Terschelling. Daar is de diepte ongeveer 100 meter, ten oosten van het bos van Hoorn is de diepte zo'n 85 meter. In de praktijk worden de theoretische verhouding van 1 op 40, volgens Ghijben-Herzberg, niet gehaald. Dat komt door slecht doorlatende lagen? in de ondergrond. Ghijben en Herzberg gingen er in hun theorie van uit dat de ondergrond zou bestaan uit een homogene goed doorlatende bodem. De zoetwaterbel bij West wordt door Vitens gebruikt voor de watervoorziening, daar bevinden zich ten westen van de Longway de pompputten in het bos.
Hoe de zoetwaterbel zich heeft ontwikkeld op het eiland onder de duinen weten we dus wel ongeveer. Maar hoe dat is bijvoorbeeld in de Terschellinger Polder, is al veel onduidelijker. We willen het echter wel graag weten, want wellicht is een gedeelte van dit water bruikbaar voor de drinkwatervoorziening. Meer inzicht kan verkregen worden door het maken van boringen, maar deze zijn erg kostbaar. Een andere onderzoekmethode is geofysisch bodemonderzoek.

Geofysisch onderzoek
Met behulp van geofysisch onderzoek kan onderscheid gemaakt worden tussen deelgebieden in de ondergrond met een hoge, dan wel een lage elektrische geleidbaarheid. Hoe groter het contrast in elektrische geleidbaarheid, hoe beter de deelgebieden onderscheiden kunnen worden met de diverse methodieken. Op deze wijze kunnen bijvoorbeeld klei- en zandpakketten van elkaar onderscheiden worden, maar ook zoet en zout grondwater.
Tot voor kort werden dit soort technieken op het land uitgevoerd. Dit was tijdrovend. Deze zogenaamde VES metingen werden dan ook op een zeer beperkt aantal locaties uitgevoerd. Tegenwoordig is apparatuur ontwikkeld, waarmee ook vanuit de lucht dit soort metingen verricht kunnen worden. Tijdens deze metingen wordt de aardbodem afgetast in stroken met een onderlinge afstand van 250 m en een vliegsnelheid van 140 - 160 km/h. Hiermee wordt het mogelijk in korte tijd een gebiedsdekkende meting uit te voeren, zoals nu in het kader van het CLIWAT-project.

Uitvoering en planning van het CLIWAT onderzoek
Er zijn binnen het CLIWAT project drie onderzoeksgebieden aangewezen in Nederland, een gebied in Zeeland, noordwest Fryslân en Terschelling waar de helikopter met daaronder een meetsonde laagvliegend het gebied in kaart zal brengen. Hierbij zal op 80 - 100 m boven maaiveld worden gevlogen met een helikopter. Onder de helikopter bevindt zich een kabel met een meetsonde die zich op een hoogte van 40 - 60 m boven het maaiveld voortbeweegt. Op Terschelling worden het onderzoek uitgevoerd met het zogenaamde SkyTEM meetsysteem van de Deense universiteit van Aalborg. Na de uitwerking van de meetgegevens zal Vitens deze gebruiken bij de Pilotstudie Watervoorziening Terschelling.

De helikoptervluchten en metingen op Terschelling zullen plaatsvinden op 16 en 17 september 2009. Gevlogen wordt boven de polder en de duinen, boven het middelste gedeelte van het eiland. De uiteinden van het eiland, de Boschplaat en de Noordsvaarder zullen worden gemeden, zie bijgaand kaartje.

Om dit onderzoek, met het laag vliegen met de helikopter, te kunnen uitvoeren zijn diverse vergunningsprocedures doorlopen. Door onderzoekinstituut Imares (Texel) is een inschatting gemaakt naar de mogelijke verstorende effecten van deze vluchten op vogels en zeehonden. Om de verstoring te voorkomen wordt niet laag gevlogen boven open water. Bovendien wordt gevlogen tijdens laagwater zodat de hoogwatervluchtplaatsen op en bij het eiland veelal niet bezet zullen zijn. De vogels zitten dan op het wad. Door de uitvoerders van de vluchten is bij de luchtvaartpolitie ontheffing aangevraagd voor het lager vliegen beneden de wettelijke vlieghoogte.

Arjen Kok
Vitens

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② de T…

Donderdag 24 sep…

Nieuws- en adv… voor Terschelli…
Oplage 4500
Verschijnt iede…

DEZE …

de Agenda Ters…
Start nieuwbou…
De Stiles
Familieberichte…
Politieberichten
de Puzzel
Jutters
Sport

New Island… in New… afgesl…

Mit dem Boden… Grundwasser a…

Zwei Studenten aus Münster untersuchen den Boden: Dabei geht es um Daten für ein Klimaschutz-Projekt – und nicht um Daten für ein mögliches Endlager.

Südtondern/sh:z – Am Heckfenster des weißen Busses prangt das schwarz-gelbe Schild der Widerstandsbewegung gegen das CO_2-Endlager. „Aus Solidarität", sagt Stephan Lessing. Der Geophysik-Student aus Münster untersucht mit einem Bodenradar die Grundwasservorkommen. Er und sein Studienkollege Matthias Lischper sehen sich dabei im Zuge der Endlager-Diskussion vor ein besonderes Problem gestellt: Sie stoßen auf Misstrauen und wachsame Bürgermeister, die ihnen den Zutritt zu den Gemeindeländereien verwehren.

Dabei sind die beiden Studenten von der Universität Münster tatsächlich in Sachen Klimaschutz unterwegs und nicht auf der Suche nach geeigneten Flächen für ein CO_2-Endlager. Sie arbeiten für das Projekt Climate and Water, abgekürzt CliWat, in dem es um die Auswirkungen des Klimawandels auf die Region geht. „CliWat soll helfen, die regionalen Veränderungen im Wasserhaushalt und die daraus resultierenden Auswirkungen zu erkennen", heißt es dazu in einer Projektbeschreibung des Landesamtes für Landwirtschaft, Umwelt und ländliche Räume. „Das hat mit den anderen Untersuchungen auch nicht das geringste zu tun," bestätigt auf Anfrage Dr. Michael von Abercron. Der Leiter des Ministerbüros im Landwirtschafts- und Umweltministerium in Kiel verweist darauf, dass es um die Auswirkungen der Klimaeinflüsse auf die eiszeitlichen Grundwasserleiter geht.

Durch die erwarteten höheren Niederschläge im Winter kann es zu einem Anstieg des Grundwasserspiegels kommen. Außerdem wird mit einer zunehmenden Belastung des Oberflächen- und Grundwassers durch Auswa-


Mit dem Boden-Radar unterwe…

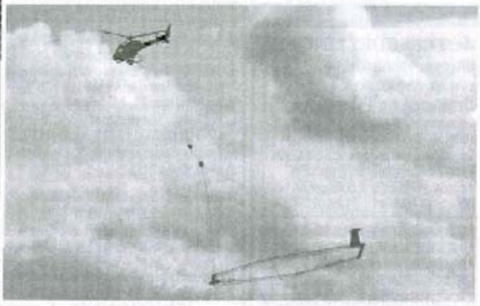
Förderung aus Nordsee-Programm

Das Projekt CliWat wird gefördert aus dem Nordsee-Programm Interreg IV B für regionale Entwicklung. Im Rahmen des Projektes finden in sieben Pilotgebieten in den Niederlanden, Belgien, Dänemark und Deutschland wissenschaftliche Untersuchungen statt. Eines dieser Projektgebiete befindet sich grenzübergreifend in Nordfriesland und Südjütland. Das Projekt wird vom Landesamt für Landwirtschaft, Umwelt und Ländliche Räume und vom Miljöcenter Ribe betreut. Die Daten dienen als Basis, um die regionalen Klimaveränderungen und deren Auswirkungen abschätzen zu können. Danach sollen Anpassungsstrategien für die Land- und Wasserwirtschaft sowie die Planungen der Infrastruktur entwickelt werden. Das Projekt läuft von 2008 bis 2011 mit einem Gesamtbudget von 5500000 Euro. Die Hälfte wird über das EU-Programm gefördert.

TERSCHELLINGER

ptember 2009, Nr. 1237 — Losse nummers € 1,10

Grondmetingen met helikopter



Dezer dagen vloog boven Terschelling een helikopter met daaronder een kabel met een meetsonde lang over.
Zoals gemeld betrof het hier een onderzoek van de Provincie Fryslân, Wetterskip Fryslân en Vitens. Het doel van de metingen is het in kaart brengen van de opbouw van de ondergrond en de diepte van zout grondwater. Het in kaart brengen van zout grondwater maakt deel uit van een Europees project (CLIWAT). Het gaat erom inzicht in de effecten van klimaatverandering op de waterhuishouding in Noordwest Fryslân en op Terschelling te krijgen. De opbouw van de ondergrond en de diepte van het zoute grondwater wordt gedetailleerd in kaart gebracht. Deze kaart dient als basis voor nader geohydrologisch (model)onderzoek.

Rolf Johnsen (i baggrunden) tjekker boringen ved Madevej, og de elektroniske oplysninger sendes over i Lars Ernsts computer. (Foto: Martin Ravn)

Geologer holder godt øje med grundvandet ④

EU-projekt skal afhjælpe klima-problemer i bl.a. Horsens

Tekst: Kirsten Rudkjøbing
Foto: Martin Ravn

HORSENS - Gennem 20 boringer tjekkes vandkvaliteten og vandspejlet på grundvandet i Horsens hvert kvarter.

På den måde forsøger geologerne hos Region Midtjyllands afdeling for jord og råstoffer at danne …

Den viden skal bruges til at foregribe og afhjælpe de problemer, der kan opstå ved øget nedbør og stigende havspejl i forbindelse med klimaændringer.

Det er den lokale del af et stort klima-projekt, som er sat i gang inden for EU med samarbejdspartnere i Danmark, Tyskland, Holland og Belgien.

I forbindelse med projektet har region Midtjyllands bore-bil lavet 12 nye boringer i Horsens. Der var otte i forvejen.

Hullerne, der er mellem tre og 10 meter dybe er lavet forskellige steder i byen: I villakvarteret på Poppelvej, i det gamle indu- …

Region Midtjyllands borebil har lavet 12 nye borehuller i Horsens og skal videre til den tyske ø Borkum for at bore. (Foto: Lars Ernst, Region Midtjylland).

… billede af, hvor langt ind grundvandet vil blive påvirket af tidevandet, og hvordan det vil blive påvirket af ændrede nedbørsforhold. Det gør vi for bedre at forstå vandets kredsløb i Horsens. På den måde kan man forebygge oversvømmelser og ved oversvømmelse lede vandet det rigtige sted hen. Hvis vandet er forurenet, skal det ledes …

… urenes af pesticider, olietanke, utætte kloakker og lignende.

Region Midtjyllands borebil skal også en tur til den tyske ø Borkum, en af …

… stigning på en halv meter. Den halve meter havspejlsstigning er også gældende for Horsens. Der vil komme oversvømmelser, og vi skal have vandet ud …

… havn op til klimakonferencen.

- Klimaforandringer er en fælles udfordring, men problemstillingen i de enkelte lande er forskellig. Vi udveksler viden. Holland og Belgien ligger meget lavt, og hollænderne er meget længere fremme med at styre vandspejlet. Det kan vi lære noget af, siger Rolf Johnsen.

- Det er en problemstil- … r relevant for rig- … e mennesker, og … ges resultaterne … egruppe af inter- … Vi prøver at sam- … skabe en proces, … de sig som ringe … t, siger Rolf

FAKTA

EU-projekt

EU-projektet Cliwat kører over tre år og har et budget på 40 mill. kr.

Halvdelen af pengene betales af EU's Nordsøprogram.

Der er 16 samarbejdspartnere i projektet, bl.a. Region Midtjylland og Horsens Kommune.

Regionens budget er på godt fem mill. kr., hvoraf EU betaler 2,8 mill. kr.

Projektet, der foregår i Danmark, Tyskland, Holland og Belgien, koordineres fra Region Midtjyllands afdeling for jord og råstoffer.

Afdelingen ligger på Bastian i Horsens. Projektleder er geolog Rolf Johnsen.

Region Midtjylland laver også undersøgelser på den nedlagte Eskelund losseplads ved Århus.

Der er lavet en følgegruppe af interessenter bestående af bl.a. Banestyrelsen, Vejdirektoratet, VIA Horsens, Danmarks Tekniske Universitet, Rådgivende Danske Ingeniører, Geoteknisk forening, Danmarks Naturfredningsforening og en række kommuner, der følger resultaterne af projektet undervejs.

…-Radar dem …uf der Spur ③

…gs: Stephan Lessing (l.) und Matthias Lischper. Foto: uw

… schung von Düngemitteln und Pestiziden sowie aus Altlastenflächen gerechnet, heißt es in der Projektbeschreibung des Landesamtes. „Es ist wichtig zu erfassen, wohin das Wasser fließt", erklärt Stephan Lessing dazu. Es könne zum Beispiel passieren, dass sich bei größeren Einträgen die Fließrichtung ändert und schadstoffhaltiges Wasser in die Nähe von Brunnen in einem Wasserschutzgebiet gelangt. „Um solche Effekte abschätzen zu können, werden die Messungen gemacht", erläutert Stephan Lessing.

„Es ist wichtig zu erfassen, wohin das Wasser fließt."
Stephan Lessing

„Wir fahren die Feldwege entlang und mit diesem Gerät schauen wir in den Boden und können sehen, wie tief das Grundwasser liegt", erklärt Stephan Lessing und deutet auf das Stangengerüst mit den zwei grauen Kästen hinter dem Kleinbus. Der eine enthält den Sender, der andere den Empfänger des Bodenradars. Stabilisiert wird das Ganze mit einer Dreirad-Konstruktion, die unmittelbar an den Kleinbus gekoppelt ist. Das Bodenradar funktioniert nach dem Prinzip eines Echolots. Die Daten erfasst ein Computer im Bus und stellt in schwarz-weiß das geologische Muster des Untergrundes dar, aus dem sich die Beschaffenheit des Bodens und der Verlauf des Grundwasserspiegels erkennen lässt. Mit dem Bodenradar wird der Untergrund bis in Tiefen von zehn bis 20 Meter erfasst, erklärt Stephan Lessing und versichert, dass die Daten nur für seine Diplomarbeit und das Projekt CliWat verwendet werden.

Begonnen wurde mit den Messungen im Mai in Süderlügum. Inzwischen haben sich die beiden Studenten entlang der deutsch-dänischen Grenze von Süderlügum bis Medelby vorgearbeitet. Weitere Messungen stehen in den nächsten Wochen im gleichen Gebiet, eventuell auch auf Föhr an.

Zusätzlich wird für das Projekt CliWat das Leibnitz Institut für Angewandte Geophysik (Hannover) ab dem 10. August seismische Messungen im Bereich Süderlügum durchführen. Es handelt sich dabei um die Fortsetzung der Messungen vom Mai dieses Jahres, über die bereits berichtet wurde.

UTE WEISS

17.07.2009

Klimawandel und Grundwasser

Wrixums Bürgermeisterin Heidi Braun staunte nicht schlecht, als sie beim Gemeinde-Biotop unerwartet auf einen Messtrupp stieß. Das Geheimnis war rasch aufgeklärt: Der Trupp nahm seismische Messungen zur Ergründung des Föhrer Grundwassers vor, die beim Amt ordnungsgemäß angemeldet waren. ⑤

Föhr/len – „Unsere Messungen auf der Insel haben in keiner Weise etwas mit den Überlegungen zur CO_2-Verpressung zu tun". Dr. Helga Wiederhold vom Leibniz-Institut für angewandte Geophysik in Hannover sind die Befürchtungen der Nordfriesen in Bezug auf Planungen der Energieunternehmen sehr wohl bewusst. Deshalb finden ihre ersten Messungen zum EU-Projekt „Cliwat – Climate and Water" nicht wie ursprünglich geplant bei Leck, sondern bei Wrixum statt.

„Unsere Messungen haben nichts mit der CO_2-Verpressung zu tun."
Dr. Helga Wiederhold, Projektleiterin

„Unsere seismischen Messungen erreichen außerdem nur eine Tiefe von etwa 200 Metern und sind also längst nicht so tief wie etwaige Untersuchungen zur CO_2-Einlagerung, die über 1000 Meter weit reichen würden", so Wiederhold weiter.

Bei diesem Vorhaben, das aus dem europäischen Interreg IVB-Nordsee-Programm kofinanziert wird, geht es, wie die Wissenschaftlerin berichtet, um den Einfluss des Klimawandels auf die Grundwassersysteme. Von Belgien über die Niederlande, den deutschen Küstenbereich und Dänemark erstrecken sich die Projektgebiete, wobei in Schleswig-Holstein das Landesamt für Landwirtschaft, Umwelt und ländliche Räume mit im Boot ist.

„Der Klimawandel wird den Kreislauf des Wassers beeinflussen", davon ist Helga Wiederhold überzeugt. Zunehmende Niederschlagsmengen werden zu Anstieg und Ausweitung des Grundwasserspiegels führen und könnten, gerade auch auf Föhr, zur Folge haben, dass die Süßwasserlinse und das Salzwasser des Meeres in Kontakt kommen, womit die Trinkwasserversorgung vor massive Probleme gestellt würde.

Der erste Schritt dieses Projektes, das sich über mehrere Jahre erstreckt, war übrigens bereits im vergangenen Jahr über Föhr und Nordfriesland zu beobachten: Bei Hubschrauberbefliegungen wurde die elektrische Leitfähigkeit der einzelnen Gebiete systematisch erfasst.

Bei den seismischen Messungen, die bis zum 20. August auf der Insel durchgeführt werden, wird erforscht, wie die Schichten des Untergrundes aufgebaut sind. Dazu sendet ein Spezialfahrzeug, der Vibrator, Schallwellen – ähnlich einem leichten Erdbeben, in den Untergrund. Sie werden von den verschiedenen Formationen reflektiert und durch so genannte Geophone, die alle zwei Meter entlang einer etwa 1200 Meter langen Messlinie in den Bo- …

Musste mit ihrem Projekt auf die Insel Föhr ausweichen: Dr. Helga Wiederhold. Fotos: len

… puters im Messfahrzeug dargestellt. Die Geophysikerin vergleicht dieses Messverfahren, die Reflexionsseismik, mit einem Echolot, das auf Schiffen zur Feststellung der Meerestiefe eingesetzt wird. Dabei ist dieses Verfahren so empfindlich, dass Fußgänger, Ponys und sogar der Wind, der durch das Gras streicht, auf dem Monitor von Siegfried Grüneberg sichtbar werden. Zum Messtrupp gehört auch Eckhardt Großmann, zuständig für den Vibrator und den zur manuellen Herstellung von Schallwellen eingesetzten Messhammer.

„Es entsteht bei den Messungen ein unendlicher Wust an Daten die dann später am Rechner verarbeitet werden müssen", klärt Helga Wiederhold auf. Hier werden die verschiedenen Messungen, wozu auch frühere Bohrungsergebnisse gehören, zu geologischen 3-D-Modellen der Küstenregionen zusammengefügt. Diese Bestandsaufnahme der einzelnen Grundwassersysteme soll letztlich zusammengefasst werden und zu Handlungsempfehlungen führen. Doch bis dahin …

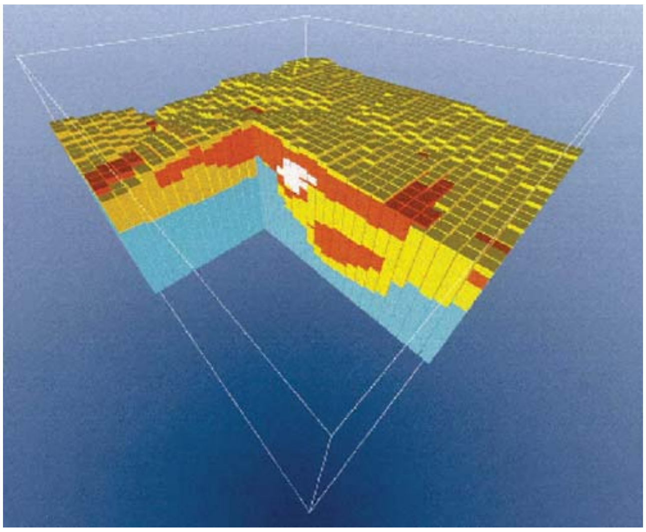


Figure 2: *Modelling the geology with voxels (volumetric pixels)*

The main objectives of the Egebjerg project

The main objectives of the Egebjerg pilot area are to develop a 3-D geological model, to map the spatial distribution of subsurface groundwater bodies, and to evaluate quantitative and qualitative effects of climate change on groundwater and surface water from simulations generated by an integrated hydrological model. The hydrological model will use data from the Intergovernmental Panel of Climate Change (IPCC) climate scenarios (A2 and B2). The results will provide an important input (as well as tool) for current and future quantitative and chemical status assessments of groundwater according to the Water Framework and Groundwater directives as well as for the planning of strategies for flood defence. The results will also be accompanied with guidelines and recommendations for the management of the water supply and the protection of the groundwater resources.

Output of the modelling work:

- Determine the local effect of climate change on groundwater resources;
- Quantify and visualise the changes to groundwater and surface water flow;
- Evaluate protection strategies and methods for groundwater reservoirs and capture zones (well fields) under changed climatic conditions;
- Devise guidelines for hydro-geological mapping in Denmark in the context of climate change;
- Devise guidelines for managing groundwater resources in relation to environmental standards, groundwater protection plans (water plans) and adaptation strategies.

The modelling work will be carried out in close cooperation with the Geological Survey of Denmark and Greenland (GEUS). In particular, the hydrological model will be modified in relationship to the Egebjerg area and the objectives of the CLIWAT project. The geological modelling software is GeoScene 3D (for more details visit www.i-gis.dk), and the integrated hydrological modelling uses the MIKE SHE software (for more details visit www.dhigroup.com). The geology is modelled in voxels (volumetric pixels) in blocks of 5 x 100 x 100 metres (see Figure 2). The geological model will be completed in April 2010. Figure 2 illustrates a part of the interpreted geo model.

The Roosmalen regional study

Using a distributed hydrological simulation model, a study of projected regional climate change effects in Denmark on groundwater recharge, storage and discharge to streams was carried out by van Roosmalen et al. (2007). Increase in precipitation, temperature, and potential evapotranspiration were predicted in each of the two 30-year climate scenarios (IPCC A2 and B2). Groundwater recharge as well as resulting subsurface storage and discharge were predicted to increase in sandy soils, while only small changes were predicted in clayey sediments and soils. Climate change effects on groundwater recharge and discharge to streams were found to vary seasonally. Potential effects of climate change on water availability were also predicted to vary seasonally. The geological factors are vital for the results of the modelling. The results and methods of this study are used as a 'path finder' for the investigations and modelling work in Egebjerg. The Egebjerg area represents a local scale (clayey sediments), so it is obvious its outcome should be compared with the outcome of the van Roosmalen study, which was carried out on a regional scale.

Perspectives

Because of the National Groundwater Mapping Project and other national databases, a lot of groundwater data and geophysical data are readily available in Denmark. On the basis of the existing data and models, it is possible to illustrate the effects of climate change on a national scale but not on a local scale. Groundwater models need to be developed that can predict local change. The availability of local-scale data and data coverage is therefore vital for the models. Adaptation strategies based on national or local-scale models may be quite different. Local factors more or less directly affect the adaptation strategy, for instance in the case of waterworks. The work and conclusions of pilot area Egebjerg F will make an important contribution to local-scale expert knowledge, especially in clay dominated sediments. The same kind of modelling should be done in other geological settings to compare and evaluate the variability.

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Freshwater – Our most important resource. Geology and groundwater models. No.1. April 2001, GEUS

Groundwater and Climate Change: Challenges and Possibilities, BGR 2008

Links:

www.ipcc.ch/ (Intergovernmental Panel of Climate Change)
http://gerda.geus.dk/ (Danish geophysical database)
www.blst.dk/English/ (Danish Agency for Spatial and Environmental Planning)

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The pilot survey on Terschelling

by Arjen Kok and Esben Auken

In autumn 2009 a survey coast was conducted on the island of Terschelling in the Dutch North Sea. Using the SkyTEM system aboard an aircraft an overall distance of 400 km was covered. The aim of the survey was to identify the fresh-salt water boundary.

Results from the survey reveal that the fresh-salt water boundary can be accurately mapped together with the clay layers which control the groundwater flow to some extent. Furthermore, the outflow of freshwater to the sea is mapped several hundred metres distance from the shore line and more than 10 m below the North Sea surface. In March 2010 all these field data were combined with helicopter data from another survey, and interpreted during a two-day meeting in Århus. Geophysicist from Denmark shared their knowledge with Dutch geophysicist and hydrologists. The results correlate significantly with CPT's, ground-based CVES and TEM measurement and boreholes. With this information the existing geo-hydrological model can be updated, which provides an excellent basis for modelling the effects of sea level rise.

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"Climate In Practice"– an innovative outcome of the CLIWAT project

by Rolf Johnsen

During the last six months, Central Denmark Region has gathered experts from Danish universities, engineering consulting companies and knowledge centres to discuss climate change issues.These workshops helped to obtain a better understanding of climate change-induced water challenges the region will face in the future. This project runs in parallel to the CLIWAT project.

The aim of the *Climate In Practice* project is to provide local businesses with a better knowledge platform from which they may innovate and create new products that can address the expected challenges related to climate change and water. Six workshops were held, each on its own specific topic:

Stakeholders and experts during the workshop (© Karsten Arnbjerg-Nielsen)

- Open country (new nature, wetlands, changed conditions for agriculture);
- Water supply, groundwater protection, outwash of pollutants;
- Surface water and sewage and treatment plants and systems;
- Safety of infrastructure, residences, buildings and other technical equipment;
- Planning and urban development;
- Cross sectors.

One of the key messages from the workshops was the need to handle water locally, to prevent down stream damages during flood events. Furthermore, it is important that people cooperate across sectors to build the most robust and sustainable solutions.

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Evaluation of landfill disposal boundaries by means of induced polarisation and electrical resistivity imaging

by Aurélie Legaz, Esben Auken and Anders Vest Christiansen

In November 2009, researchers from the HydroGeophysics Group, Aarhus University started a survey of the former municipal landfill Eskelund (Denmark). Induced polarisation measurements (IP) and electrical resistivity tomography (ERT) were used to define the spatial boundaries of the dump site. The joint application of these two methods allows the discrimination between materials displaying an identical signature in resistivity (e.g., brine and clay).

The Eskelund landfill belongs to a complex of four landfills,covering an area of approximately 0.15 km^2. The site has been uncontrolled, and was established without any kind of membranes, leachate capture or isolation systems.

The Århus university crew installing the rick for drilling

The waste mainly consists of domestic waste, but also industrial waste including oils and chemical waste. The landfill was established in the meadows adjacent to Århus creek.

Previous geo-chemical surveys and underground water samples confirm the contamination, resulting from water seepage through the landfill. The substratum of the waste mainly consists of mud and silt; the silt layer provides only slight protection from percolation from the landfills. Moreover, the silt layer leaks at some places, which results in a direct contact between the waste and the underlying aquifer.

The goal of this work is to characterise the spatial boundaries of the Eskelund landfill itself, and to investigating the contamination plume in the vicinity of the waste site. In general this work contributes to develop an efficient tool for the characterisation of abandoned landfill areas. If conclusive, this tool could be applied for the recognition of a large number of buried and abandoned dump sites all over Europe. The overall area was investigated with the collection of 12 profiles of 355 m depth each. In collaboration with Region Midtjylland, the dataset was then completed by an El-log drilling to a depth of 24 m. The drilling was made with the intention to collect in-situ resistivity and induced polarisation data for accurate correlation between the geology and the geophysical measurements. These data were measured every half meter (an article was dedicated to the drilling in the Århus newspapers, see http://stiften.dk/article/20100125/AAS/701259959/1002). Soon we will be able to provide a 3-D model of the data with joint interpretation of drilling information of the near surface geology (up to 50 m depth). As soon as these images and results are available, they will be published on the CLIWAT web page.

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First CLIWAT transnational board meeting

by Sophie Rotter

Following the project partner meeting stakeholders from the four case study countries came together for the first transnational board meeting of the CLIWAT project. During this meeting a broad overview of the various national approaches to adapt to climate changes on water related issues was given with regard to national, regional and local scaling levels. Clear differences could be mapped between the various countries.

Project partners applying card sorting method (© Klaus Hinsby)

During the discussion the most essential requirements for policies and measures to adapt to climate change focusing on groundwater in each of the countries could be identified. Furthermore, the participants pointed out which already existing policies and measures need to be adapted. Finally, the participating project partners highlighted which of the identified adaptation requirements could be supported by CLIWAT project results. The discussion was guided by using the so called card sorting method which helps to structure the discussion. The participants were asked to fill in a structure making sure that all important topics are covered and documented.

In the following a short overview over the main discussion outcomes is given. Not surprisingly, since 2008 strategies to adapt to climate change are implemented in all four countries (Belgium, Denmark, Germany, the Netherlands). However, the extent of the progress with implementation differs significantly. In Denmark and Germany currently potential impacts of climate change are mapped, and are incorporated into the planning of potential measures on the national level (German Action Plan for the Adaptation in 2011). The Netherlands and Belgium, however, are already a step further having identified the most effective measures to protect their countries against damages, taking sea level rise into account. This is expressed in the *Dutch Delta Programme* and its counterpart in Belgium – the *Sigma Plan*. Moreover, in Belgium further initiatives are on the way, as for instance the *Flemish Adaption Plan*, which is due in 2012. Another example is the integrated master plan for Flanders' future safety which is supposed to keep the coast safe until 2050.

Further differences between the countries also exist in respect to activities regarding adaptation strategies to climate change. Due to the political system in Belgium adaptation efforts are only made on regional and local level, whilst in Denmark the regions are not much involved at all. Discussing the most urgently required policy instruments and measures in the various countries CLIWAT results that meet these needs were identified.

In Belgium for instance, groundwater flooding is at the moment not taken into account in climate change scenarios. CLIWAT will deliver models that includes this information. Furthermore, groundwater and and surface water interaction is modelled in Zeeland as well as at the German-Danish boarder. The demand of the German stakeholders not to follow a regional but an eco-regional approach is implemented along the 'eco region' islands Borkum, Föhr and Terschelling. Appreciated policy instruments in Denmark are guidelines taking climate change into account, for example, when building roads. Policy recommendations being delivered by CLIWAT based on an improved knowledge on the potential development of groundwater bodies in the future could support this process. In the Netherlands the CLIWAT models will support decision makers with regard to future land use and water supply, which was seen as an important issue to be solved. The models are here focused on the salinisation of ground water but can also be used in other perspectives. In a nutshell CLIWAT results will improve the knowledge on the effect of climate change on groundwater bodies. Longer term discussion in society can be based on forecasts to be used on regional level. However, there are, of course, limitations as well. Meaningful modelling on local scale is not feasible at the moment, and climate models introduce uncertainty which cannot be avoided. For more information please refer to the meeting minutes on our website.

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Schedule of events

Date	Event	Content	Location	Link
29/9-1/10/2010	Deltas in Times of Climate Change	International conference on climate change issues in deltas	Rotterdam, The Netherlands	http://www.climatedelta conference.org
18/09/2010	2. Borkumer Tag der Energie	open house	Stadtwerke Borkum, Germany	http://www.stadtwerke-borkum.de/
9-11/08/2010	XXVI Nordic Hydrological Conference	NORDIC WATER 2010: From research to water management	Riga, Latvia	www.nordicwater-2010.com
5-8/7/2010	iEMSs	International Congress on Environmental Modelling and Software	Ottawa, Canada	www.iemss.org/iemss2010
21-25/6/2010	$2^{st}4$ Salt Water Intrusion Meeting (SWIM)	SWIM21 – AZORES 2010 this year at the University of Azores	São Miguel, Azores, Portugal	http://www.swim21-azores2010.com/
May/June 2010	CLIWAT field measurements	DC/IP (AU)	Århus River, Denmark	
18/5/2010	Danish national board meeting	National meeting of Danish CLIWAT stakeholders	Bygholm Hotel, Horsens, Denmark	http://cliwat.eu/
11/12/5/2010	CLIWAT Partner Meeting	CLIWAT partner meeting in Akademie Sankelmark	Oeversee, Germany	file:www.akademie-sankelmark.de
April/July 2010	CLIWAT field measurements	CVES and CPT's (Vitens) measurements	at sea and in Fryslan, Netherlands	
April/June 2010	CLIWAT field measurements	DC/IP, magnetics and TEM (AU)	H/orl/okke, Denmark	
April/May 2010	CLIWAT Field measurements	gravity survey (EC-Ribe)	South Jutland, Denmark	http://cliwat.eu/
12-23/04/2010	CLIWAT Field measurements	seismic survey by LIAG	Föhr, Germany	http://cliwat.eu/
11-17/4/ 2010	ICCCM10	International Conference on Coastal Conservation and Management in the Atlantic and Mediterranean	Estoril, Cascais, Portugal	http://icccm.dcea.fct.unl.pt
April 2010	CLIWAT field measurements	methane flux estimation (RM)	Århus River, Denmark	
23/03/2010	Norddeutscher Interreg IV – Wasserworkshop	Northern German Interreg IV workshop on water	Bad Bevensen, Germany	

The above dates and locations may change. The editors are neither responsible nor liable for any inconvenience resulting from such changes.

Imprint

CLIWATInterRegNewsletter is published on a semestral base in PDF format.
Press date for the April issue: 6^{th} of April 2010
Publisher: Seecon Deutschland GmbH
Contact: info@seecon.org
Editors: Sophie Rotter and Jörg Krywkow, Seecon

This newsletter is an output of the EU InterReg project CLIWAT, (Interreg IVB journal no.: 35-2-1-08). The project is partly financed by the European Regional Development Fund under the European Union.