

## *Water management: a combination of physical and social sciences*

**Professor Martin Wassen is the theme leader of the UCG theme of Management and exploitation of natural resources. He studied biology in Nijmegen and Groningen and graduated in 1983. He obtained his PhD in 1990 from Utrecht University. He stayed in Utrecht afterwards and was appointed Professor of Landscape Ecology in 2003.**



'When I became a professor, my teaching remit was to integrate landscape ecology with other disciplines. This teaching remit ties in well with the theme of management and exploitation of natural resources. It was the last theme to kick off within UCG, and our first PhD student started in March 2005.

I have always wanted to be a researcher. When I was a child I wanted to become an ornithologist, a combination of biology and birds. In the end I did study biology, but I am now looking more into landscapes, water and plants. I never really lost my love of wildlife entirely as I am now an amateur birdwatcher.

Within this theme, we are studying the fragmentation of ground-water systems and their impact on the wet ecosystems in the west of the Netherlands. We are also looking at human interference caused by urbanization, agriculture and water management. Our current research focuses on the operation of ecosystems and how we can bring back natural ecosystems in the Netherlands through proper water management. Three PhD students were appointed in March and April 2005. One of them will be studying ecosystems from a hydrological perspective, another from an ecological perspective and the third will be using the data gathered by the other two to develop a decision-support system that will enable water managers to evaluate the effects of their water management in advance.

Water management is a key element of the Dutch Ministry of Transport, Public Works and Water Management's policy. Effective policy and management needs public support. It should also be cost-effective and allow other activities that depend on water, such as the extraction of drinking water, agriculture and shipping, to continue uninterrupted. It is important, therefore, that the pure, physical sciences cooperate with social sciences so that we can all contribute our different perspectives on the issues involved in water management. The potential consequences of climate change for our low-lying country mean that we clearly see how relevant water-management issues currently are in various disciplines.

It is both challenging and fascinating to work as an ecologist in areas overlapping other disciplines. I welcome ecologists who choose to broaden their horizons after initially specialising in a specific area within their own discipline. This is what generates true innovation. Of course, you cannot expect that combining several disciplines will all be plain sailing. There will be differences in research traditions, scale, different research processes and different techniques and models. The objective is, therefore, to establish new scientific paths together and come up with new ideas and solutions. And getting social scientists to cooperate with physical scientists will be the next bridge to cross in the future.

UCG also makes it possible for me to meet scientists from many other disciplines. The current contacts between TNO and Geosciences, for instance, provide different perspectives on the same subject. And this enables us to file joint applications for research funding.

As a scientist, it is refreshing to encounter completely different disciplines within the geosciences. For example, the consequences of disposing CO<sub>2</sub> in empty gas reservoirs raised completely new scientific issues for me.'

### *Remediating disturbed systems*

**Arnaut van Loon graduated early 2003 from Wageningen University at the department Soil science, Hydrology & Water quality and Meteorology & Air quality in early 2003. He majored in hydrology and water management, with a focus on the use of geohydrology, hydraulics and physical and mathematical modelling. Before he embarked on his current PhD research *Defragmentation of groundwater dependent ecosystems for spatially coherent nature management* in March 2005, he worked for the Dommel Water Board for a year, where his job as a junior advisor included drainage studies.**

'When I was working on my subsidiary subject of theoretical hydrology, I realised that I really wanted to do a PhD. I am not sure yet whether I want to keep doing research after I have completed my PhD. I really enjoyed working at the Water Board, but did not find the challenges I was looking for. I came across this research job on the Academic Transfer website and applied.

I am part of a team of three young researchers. Our objective is to develop a decision-support system for spatial coherent water management. This system will be a useful tool to enlarge our understanding about the interacting ecological and hydrological key-factors controlling the viability of rare species. With this knowledge optimal measures can be designed aiming to restore disturbed systems. Disturbed systems are systems that have been adversely affected by human activity.

My research compares how natural ground-water systems evolve in comparison with disturbed ground-water systems. When a system is affected by human activity, it frequently becomes fragmented. I am studying the consequences of fragmentation on the basis of hydrochemical processes. Changes in transport systems may induce chemical reactions. I am developing hydrological models and linking these to chemical models. These models are then validated using field observations. The disturbed system I am studying is the Vecht region in the Netherlands, which I am comparing with the undisturbed system of the Biebrza in Poland. One of my co-researchers is working on the same topic, but from an ecological perspective. All these results will be applied as variables in the decision-support system, which is being developed by my other co-researcher.

The combination of modelling and fieldwork is a way of seeking to interpret the past by gathering data in the present. It is true multidisciplinary research, combining hydrology with chemistry, physical geography, palaeohydrology and some aspects of ecology. Since I have only just started, I have not yet met many other specialists in these disciplines. But I definitely consider it an advantage to have all this expertise close at hand. I am also cooperating with TNO-NITG and will eventually exchange knowledge and data with them.

I enjoy finding my own way in this project. It enables me to pick the best bits for myself. I am also developing myself by learning more and getting to know other people working on similar issues. On the other hand, studying the same issue in a team of three people is certainly also very enjoyable.'

### *Fundamental research for technical applications*

**Frank van Bergen graduated in geochemistry from Utrecht University with Professor Jan de Leeuw. His internship in petroleum geochemistry paved the way to a job at TNO. He has been working as a geoscientist at TNO since 1998 and his work involves petroleum systems and CO<sub>2</sub> sequestration in coal. In 2003 he embarked on his PhD study related to CO<sub>2</sub> storage via enhanced coalbed methane production, which is part of the UCG theme of Geo-energy.**

'Many countries have committed themselves, by the verification of the Kyoto protocol, to reduce their emission of greenhouse gases. This implies that on short-term, technology should be developed that provides energy without CO<sub>2</sub> emissions, while economic growth is maintained. At TNO, my work involves the study of opportunities and applicability of storage of CO<sub>2</sub> in the subsurface. This is considered to be one of the few options that can contribute significantly to this emission reduction in the near-future. In particular, I am considering the opportunities for storage options in underground coal beds. The final goal of the research is the development of a zero-emission cycle; production of fossil fuels combined with CO<sub>2</sub> storage after conversion into energy or chemical products. At the moment TNO is coordinating a consortium of companies and universities that are running a demonstration project of this technique in Poland.

This field test shows that as yet, the fundamental understanding of the processes involved is only limited. As it now appears, some of the earlier assumptions have not been sufficiently verified, and I consider it a challenge to improve this understanding. In the scope of the UCG, TNO offers me the opportunity to do part-time fundamental research at the university, while I continue to work on the applications during the rest of the week.

My research at the university is focusing on the interaction of CO<sub>2</sub> and coal under reservoir conditions, among others by using Infrared Spectroscopy. This will allow us to observe what is actually happening with the CO<sub>2</sub> at the coalface on a microscopic scale, which has never been done before.

Finally, I wish to integrate the laboratory results with the results of the field test to gain a better understanding of the actual process. I hope that some of my findings can be introduced in actual applications, such as reservoir models for these types of field operations. However, at this moment it is still too premature to say anything about the conversion of my research results into practical applications.

What I like most about this research is its relevance to problems that are or will be a part of the society. The reduction of CO<sub>2</sub> emissions is an international priority, and that is very noticeable from all the attention I get from abroad and from the media. You are not just working in your own little cubicle on a study that will never be used, that's something I would not favour. You can see that it is a very dynamic field; there have already been some new developments and improvements in the short period since I started. This makes this project rewarding. On the other hand, it can be frustrating because sometimes applications require immediate solutions, while the fundamental understanding is not yet complete. On the other hand, applications lead to fundamental questions. I therefore think that this shows that an integrated approach is the way forward in this type of research'

### *Starting small to tell something big*

**Emilia Liteanu, M.Sc., from Romania started her PhD project *Response of carbonate sediments to CO<sub>2</sub> disposal* in February 2005. Her research is on the UCG theme of Geo-energy. She did her undergraduate studies in geological engineering in Bucharest, graduating in 2001. She completed her Master's in hydrogeology at the Simon Fraser University in Vancouver, Canada in early 2004. She then returned to Bucharest for a year, where she worked as a marine geologist at GEO-ECO-MAR (Institute of Geo-ecology and Marine Geology).**

'During my undergraduate studies I became more interested in a scientific career, although I have a very broad interest in earth sciences and cannot decide which area I like best. The work I did at GEO-ECO-MAR was interesting and a welcome change from the years of studies I had behind me, but a PhD project appealed to me more. I applied to do rock mechanics research at Utrecht University via the earthworks website. Firstly, because I was interested in the project and secondly, because Utrecht is one of the best universities in Europe.

My research looks at the injection of CO<sub>2</sub>, especially the effect of CO<sub>2</sub> on carbonate rocks. I will be doing high-pressure and temperature experiments on calcite to evaluate its mechanical response. I will perform experiments on synthetic calcite aggregates and natural carbonate rocks and carbonate-cemented rock to determine the influence of CO<sub>2</sub> on time-insensitive compaction/dilatation behaviour and compaction creep, the porosity-permeability evolution, the effects of hydrocarbon content and pore-fluid salinity. I will be using a new instrument at the HPT lab to do this. I have just started and so am still reviewing literature. I've also completed the course on rock mechanics and deformation mechanisms as my previous studies did not include rock mechanics.

I became interested in socio-environmental issues during my Master's. And my current research clearly ties in with this. It is fascinating that, although I work with very small calcium crystals, I am able to tell something about what will happen if CO<sub>2</sub> is injected into an empty carbonate reservoir. In this way I can help to reduce CO<sub>2</sub> in the atmosphere, which is a hot topic at the moment.

I am working on a multidisciplinary study that combines rock mechanics with geochemistry and physics. I have a workplace at TNO-NITG one day a week. I also have contacts within the rock mechanics and geochemistry groups.

I think UCG is a very good initiative. It will create more interaction between the different departments. My experience in Bucharest and Canada has shown me that a combination of different disciplines can generate new ideas and cutting-edge research. For example, the geoscience department at the Simon Fraser University in Vancouver is a very young and small department. The scientists are in very close contact with each other. At first, the department only taught Master's students, but its research interests grew and the department now has PhD students.

I am enjoying my time here at the university, as well as in Utrecht itself, which is a very beautiful city. I have also been to Amsterdam, Rotterdam and Delft. And I can't wait to see the tulip fields. My project at UCG has enabled me to get to know a new culture.'

## *The past is the key to the future*

**Anna von der Heydt is a physicist. She specialised in hydrodynamics, specifically research into turbulence, during her PhD project at the Technical University of Twente. Following her PhD she started working in 2003 for the Institute of Marine and Atmospheric research in Utrecht on her first post-doc study *Computation of the Tertiary Ocean Circulation*, which is part of the UCG theme of Climate variability and Geodynamics.**

'When I first went to university I had no clear idea what I wanted to do afterwards. But during my PhD study I became increasingly enthusiastic about the idea of research. It really gives me a thrill to look at a topic and realise how little we know about it, how much we still have to learn and what questions we still have to answer. It is very gratifying to be able to contribute to the answers yourself and use your own imagination to pick the right research method.

Henk Dijkstra had submitted a project proposal on investigating the changes in the ocean circulation in relation to the drifting of the continents. I immediately thought it would be a very interesting topic: in the past, the climate and the ocean circulation changed drastically and frequently, and we do not anywhere near understand the causes. However, it is important to be aware of these effects if we are to understand the present-day climate and to predict what may happen in the future. The idea was that I would tackle this topic from a theoretical angle, but actually the climate affects everybody. It appealed to me immediately and so I was glad to get the chance to join in.

Twenty million years ago there was still a seaway between North and South America, the Panama Strait. An earlier study done in a simple ocean model showed that the flow direction in this strait reversed some 20 to 30 million years ago. At the same time, another strait vanished: the seaway between the Indian and Atlantic Oceans, which was located in the present-day Mediterranean area. I decided to study this flow reversal in detail. Geological data show, for example, that the corals in the Caribbean became extinct around the same time. In itself, however, that is not direct evidence of a change in flow direction. I used an American climate model that includes the ocean, as well as the atmosphere and the amount of ice on earth, to simulate the climate with and without a seaway in the Mediterranean area and compared the ocean circulation in these two cases. The model showed that when there was a seaway between the Indian and Atlantic Oceans, the water from the Indian Ocean flowed into the Atlantic Ocean and from there into the Pacific through the Panama Strait. In the absence of a seaway in the Mediterranean area, the water would flow from the Pacific towards the Atlantic Ocean through the Panama Strait. The model also showed that water coming from the Pacific Ocean and flowing into the Caribbean would be much colder than water coming from the Atlantic Ocean. This may be the link with the corals becoming extinct: if the flow direction indeed reversed, cold water from the Pacific Ocean would have flowed into the Caribbean instead of warm water from the Atlantic Ocean.

My research should be completed first half of 2005, but there are always of course some loose ends that need tying up. It is difficult, for instance, to estimate the ocean-floor topography that existed 20 to 30 million years ago, and so my simulations can always be improved. The main thing, however, that this research has raised some interesting new questions: for

instance, how did the deep-water circulation change over time, and how did this affect the climate?

This work ties in well with the UCG theme of Climate variability and Geodynamics. That is the rewarding part of UCG research, the collaboration with specialists from other fields. It makes it easier to compare modelling results with reconstruction data. I am not very familiar with, for instance, interpreting core data, and so find it very valuable to discuss these with other people who are more experienced. This combination of different types of expertise generates a deeper understanding. You can talk to people who are working in another field. Not only do you benefit from other people's expertise, but you also get to understand better what they are doing. And that means you can formulate your own questions more precisely.'

### *Broadening a geophysicist's horizon*

**Jojanneke van den Berg graduated in geophysics from Utrecht University in 2002 and is now doing a PhD there at the Institute for Marine and Atmospheric research Utrecht (IMAU). Her PhD study, *Interactions of ice sheets with the solid earth*, is part of the UGC theme of Climate variability and Geodynamics.**

'After graduating I was invited to come and meet the people at IMAU. They were looking for a geophysicist and I wanted to do a PhD. After a few meetings spent getting to know each other, we came up with a research project that both IMAU and I thought would be of scientific importance as well as fun to work on, and I was then accepted as a PhD student at IMAU.

At first, it was difficult to select a project because the range of topics is so wide. My supervisor wanted me to look into sea-level variations and I wanted the earth to have a prominent role. My research topic was eventually narrowed down to the indirect link between ice and climate. I am studying the dynamic link between the ice caps and the rest of the earth. What are the effects when the weight of an ice cap is placed on the earth? The surface of the earth will bend under the weight of an ice cap and the ice cap will, depending on climate and the local environment, grow or shrink, which in turn affects the deformation of the surface of the earth. I'm using a combination of two models to study this phenomenon. The first is an existing ice model that calculates the physics of the ice. The second is a flexural model that I have built myself, and which describes the mechanics of the earth. I have developed a method to merge these two models into a single model and can now start applying the results on Antarctica and Scandinavia.

I really wanted to do this research because it broadens a geophysicist's horizon. It enables me to understand the surface processes and the variations in climate and sea-level better, and I can pass on my knowledge of the mechanics of the solid earth. Until now, there weren't any models that incorporated the response of the earth's surface to the huge weight of the ice cap.

I am not really a UCG PhD student, but I am sure that I would have been one if the UCG had existed when I started this project. My PhD study ties in well with the UGC theme of Climate variability and Geodynamics. I can see many advantages of UCG. I benefit personally because UCG is funding my 'number crunching'. And I also have many contacts with other researchers, such as Paul Meijer, who is working within the same theme. It makes it easy to get talking or find out where to direct a particular question.

I really like being part of a group and cooperating on a single research issue. This was already the case within the IMAU department, and now it's also happening within UCG. Another benefit is that you get to hear what other PhD students are working on in the other UCG themes, and this means you keep in touch with the latest developments in the geosciences.'