Hydrology MSc

Vrije Universiteit Amsterdam - Fac. der Aard- en Levenswetenschappen - M Hydrology - 2014-2015

The Hydrology master's programme provides the student with sound scientific knowledge of how water cycles through the Earth’s atmosphere, surface and groundwater systems and how water quantity and quality are modified due to natural processes, or in response to human interference with the water cycle (e.g. pollution, land use change, etc.). This knowledge is a prerequisite for the sustainable use of our water resources that are being threatened by the continuous increase in the world’s population and the associated increase in water use and agricultural and industrial pollution. As water issues are often not restricted to a single country, the Master’s programme is strongly oriented to provide an international perspective.

The programme is strong in both hydrogeology and ecohydrology. Hydrogeology deals with (un)saturated groundwater and surface water flows on a local to regional scale (0-500 km), groundwater exploration and water quality issues in relation to the geology and land-use. Groundwater and surface water flow patterns and associated variations in the chemical composition of water due to interaction with the environment are assessed using a combination of lectures, field studies and hydrological and hydrochemical modelling workshops. Exploration and water resources assessments are made through application of water balance techniques, geophysical techniques and chemical and isotope tracer methods. Ecohydrology focuses on processes regulating the hydrological cycle and how these are affected by changes occurring at the land surface in response to human activities (e.g. deforestation, climate change). It combines micro-meteorology, (forest) hydrology, Quaternary geology, and environmental sciences to study processes that regulate how water, nutrients, sediment and gases are exchanged between the soil, water, vegetation and the atmosphere. These transfers are studied mostly on small catchment scales. A range of field measurement and sampling techniques are used including micro-meteorology, hydrology, plant physiology, soil physics, chemical isotope tracer methods, in combination with detailed, process-based models.

The year schedule 2014 - 2015 can be found at the FALW-website .
Further information about the MSc programme Hydrology.
A complete programme description can be found at the FALW-website .

Inhoudsopgave

Expired programme components Hydrology

Courses:

Name	Period	Credits	Code
Aquatic Ecology	Period 1, Period 4+5+6	6.0	AM_450137
Modern Climate Systems	Ac. Year (September), Period 1	3.0	AM_450185
Modern Geo-ecosystems	Ac. Year (September), Period 1	3.0	AM_450313
Sustainable Land Management	Ac. Year (September), Period 3	6.0	AM_1015

MSc Hydrology year 1

Vakken:

Naam	Periode	Credits	Code
Basics in Geographical Information Systems	Periode 5	3.0	AM_450226
Catchment Response Analysis	Periode 1	6.0	AM_450003
Ecohydrology	Periode 2	6.0	AM_450014
Environmental Remote Sensing	Periode 3	6.0	AM_450145
Field Course Hydrology Portugal	Periode 5+6	15.0	AM_1013
Field Course Netherlands (Measurements Techniques)	Periode 5+6	3.0	AM_450126
Groundwater Hydraulics	Periode 2	6.0	AM_450009
Hydrochemistry	Periode 4	6.0	AM_450052
Hydrological Systems and Water Management	Periode 1	3.0	AM_1012
Unsaturated Zone and Near Surface Hydrological Processes	Periode 4	6.0	AM_450021

MSc Hydrology, year 2

Opleidingsdelen:

- MSc Hydrology year 2 elective options
- MSc Hydrology year 2 compulsory modules

MSc Hydrology year 2 elective options

Vakken:

Naam	Periode	Credits	Code
Climate and Policy	Periode 3	6.0	AM_450188
Climate Modelling	Periode 3	6.0	AM_450004
Extension Master Thesis Hydrology		12.0	AM_450151
From Source to Sink: Chemical and Physical Cycles	Periode 2	6.0	AM_450146
Geothermal Energy	Periode 5	6.0	AM_450409
Global Biogeochemical Cycles	Periode 4	6.0	AM_450332
Groundwater Microbiology and Geochemistry (Geomicrobiology)	Ac. Jaar (september)	6.0	AM_450132
Isotope Hydrology	Periode 5	3.0	AM_450148
Modern Climate and Geo-ecosystems	Periode 1	6.0	AM_1124
Reflection Seismic for Geologists	Periode 4	6.0	AM_450170
Scientific Writing in English	Ac. Jaar (september)	3.0	AM_471023
Water and Policy	Periode 1	6.0	AM_468023

MSc Hydrology year 2 compulsory modules

Vakken:

Naam	Periode	Credits	Code
Groundwater Flow Modelling	Periode 1	6.0	AM_450008
Master Research Project Hydrology	Ac. Jaar (september)	27.0	AM_1104
Transport Processes in Groundwater	Periode 1	6.0	AM_450131

Aquatic Ecology

Vakcode	AM_450137 ()
Periode	Periode 1, Periode 4+5+6
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen

Coördinator	prof. dr. J.E. Vermaat
Lesmethode(n)	Werkcollege, Practicum
Niveau	400

Doel vak
1. Acquire an understanding of the complexity and biotic richness of aquatic ecosystems and the importance of the medium, water, in shaping this.
2. Acquire an understanding of the links between aquatic ecology and water quality, and develop the capacity to interpret pattersn from the one into those of the other field
3. Be able to understand, summarise, and debate papers from the primary literature selected to deepen the subjects presented with help of the text book
4. Be able to design, carry out and report on a limited field study in the waters around Amsterdam and test a self-developed hypothesis

Inhoud vak
This is an introductory course to for earth scientists interested in water that want to enrich their expertise with ecology. It can also serve to add a view on aquatic habitats for ecologists that mainly have been exposed to terrestrial habitats so far. The subject is presented at a master's level with a focus on independent exploration in the field and primary literature. The course will be taught from a basic textbook, Dobson & Frid (2009), as starting point, with excursions to papers providing depth to the chapters.

Characterisation of the content: Commonalities versus specific features of aquatic ecosystems: lakes, rivers, estuaries, the sea. Interactions between water body and surrounding land (catchment). A systems perspective: important processes and the role of biota: marginal or crucial? Interactions among biota in the food-web (predation, competition) and otherwise (the role of engineers or keystone species, mutuality, mutualism). Aquatic biodiversity: what does it mean? Biota as indicators of water and sediment quality in rivers and lakes. Aquatic ecology for water quality and quantity management.

Onderwijsvorm
1. plenary lectures (5 x 4 = 20 hrs). Lecture format: Vermaat discusses chapter content, students give a brief presentation on deepening papers. Non-presenting students are expected to have prepared by reading these chapters and the two accompanying, deepening papers (see below) before the lecture. The lecture is concluded with debate on the accompanying paper.
2. comparative fieldwork in small groups of 2-4 students: spatial gradients among and within water bodies around Amsterdam (field 2 d, lab processing 2 d), concluded by student seminars on fieldwork (4 hrs); student groups write a report on their fieldwork subject (length 5-10 pp, 11 pt Times New Roman, Introduction, Method, Results, Discussion, References containing ~ 10 papers from the primary literature)
3. literature study for deepening presentations and field work report.

Toetsvorm
Written exam (60%), fieldwork report (30%), oral presentations (both on book and lab work, content and quality, 10%). The written exam is open book.

Literatuur
Book: Dobson M & Frid C., 2009. Ecology of Aquatic Systems, 2nd edition.Oxford University Press, 321 pp; ISBN: 9 780199 297542
Selected deepening papers (liable to change, will be communicated at start of course):

Rivers
Poole GC, 2002. Fluvial landscape ecology: addressing uniqueness within the river discontinuum. Freshwat Biol 47, 641-660.
Lamouroux N, Poff NL, Angermeier PL, 2002. Intercontinental convergence of stream fish community traits along geomorphic and hydraulic gradients. Ecology 83, 1792-1807

Estuaries
Bishop MJ, Kelaher BP, Smith MPL, York PH, Booth DJ, 2006. Ratio-dependent response of a temperate Australian estuarine system to sustained nitrogen loading. Oecologia 149, 701-708.
Soetaert K, Middelburg JJ, Heip C, 2006. Long-term change in dissolved inorganic nutrients in the heterotrophic Scheldt estuary (Belgium, The Netherlands) Limnol Oceanogr 51, 409-423.

Coastal Seas
Bianchi TS, Westman P, Andren T, Rolff C, Elmgren R, 2000. Cyanobacterial blooms in the Baltic Sea: natural or human-induced? Limnol Oceanogr 45, 715-726.
McQuatters-Gollop A, Raitsos DE, Attrill M, Edwards M, Lavender S, Mee L, 2007. A new long-term chlorophyll dataset reveals a regime shift in North Sea phytoplankton biomass unconnected to nutrient levels. Limnol. Oceanogr. 52, 635-648.

Open Ocean
Worm B, and many others, 2006. Impacts of biodiversity loss on ocean ecosystem services. Science 314, 787-790.
Beaugrand G, 2009 Decadal changes in climate and ecosystems in the North Atlantic Ocean and adjacent seas. Deep Sea Res II 56, 656-673.

Aanbevolen voorkennis
Basic statistics, introduction in hydrology

Doelgroep
MSc Earth Sciences (all tracks), MSc Hydrology, MSc Biology, MSc Ecology

Basics in Geographical Information Systems

Vakcode	AM_450226 ()
Periode	Periode 5
Credits	3.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. ir. J. van Vliet
Examinator	dr. ir. J. van Vliet
Docent(en)	dr. R.A.M. de Jeu, drs. A.J. Wagtendonk
Lesmethode(n)	Computerpracticum
Niveau	400

Doel vak
To build a high level of practical skills and experience in the use of professional GIS software for data collection, integration, visualization, database design, mapping and automated analysis and management for a couple of specific earth science related case studies.

Inhoud vak
This course consists of a theoretical part and a practical part. In the theoretical part the principles of GIS are explained (database management, data acquisition and integration, spatial analysis, Web-based GIS, Mobile GIS and visualization). The practical part focuses on the use of the software package ArcGIS and is mostly applied to earth scientific study themes. The student will be trained in the use of GIS and special attention will be paid to the use of mobile GIS systems.

Onderwijsvorm
8 hours of lectures, 24 hours of practical (computer) exercises. Self study, including literature study.

Toetsvorm
Written exam (ca. 50%) and practical computer exam (ca. 50%).

Literatuur
Lecture notes, chapters from Longley et al., (2001) GIS and Science, John Wiley, selected articles

Aanbevolen voorkennis
Advice regarding previous course taken: AB_!076: GIS and digital geographical data

Overige informatie
The course coordinator for this course can still be subject of change

Catchment Response Analysis

Vakcode	AM_450003 ()
Periode	Periode 1
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. M.J. Waterloo
Examinator	dr. M.J. Waterloo
Docent(en)	dr. M.J. Waterloo, dr. H.J. van Meerveld
Lesmethode(n)	Werkcollege, Computerpracticum
Niveau	400

Doel vak
The objectives of the course are to provide the student with scientific theory, tools and methods for understanding and evaluating the response of a catchment to precipitation in terms of surface water flows. This requires knowledge about processes regulating the flow of water on the land surface and in river channels, the techniques for quantification of surface water flows and statistical methods for predicting extreme

runoff events. In addition, experience with surface water flow modelling for predicting the behaviour of rivers under different land use or climate conditions should be acquired.

The course contributes to the Knowledge and Understanding and Application of Knowledge and Understanding final attainment levels of the Msc Hydrology Programme. Knowledge and understanding is obtained through the studying of theory as provided in the reader, during the oral lectures and through self-study of scientific papers on rainfall-runoff response topics. Knowledge and understanding is applied in the setting up and execution of a rainfall-runoff model and the critical evaluation of the model simulation with measured data.

Inhoud vak
The course consists of three main topics. We start with an overview of hydrodynamic and hydraulic theory that governs flow in open channels. This is followed by lectures on discharge measurement techniques, catchment response analysis and runoff statistics. Topics are hill slope hydrology, hydrograph analysis, reservoir and flow routing and statistical methods to describe and quantify spatial and temporal variation in catchment runoff. The spectrum of available models for runoff modelling, from classical lumped models to data-demanding distributed, physically-based hydrological models, will also be discussed. Finally, theory and understanding will be applied in a series of modelling exercises applying the HBV-light rainfall – runoff model to simulate runoff of the Dinkel River in East Netherlands.

Onderwijsvorm
The tuition consists of ten classroom lectures and four computer modelling workshop sessions. The number of contact hours is in the order of 42.

Toetsvorm
The assessment is through a written exam (75%) and assessment of the modelling workshop report (25%).

Literatuur
Bishop et al. 2008. Aqua Incognita: the unknown headwaters, Hydrological Processes 22: 1239–1242. doi: 10.1002/hyp.7049.

A,.A. van der Griend and M.J. Waterloo (2013), Catchment Response Analysis. Course Reader, VU University, Amsterdam.

B.L. McGlynn, J.J. McDonnel and D.D. Brammer. A review of the evolving perceptual model of hillslope Flowpaths at the Maimai catchments, New Zealand. Journal of Hydrology 257 (2002) 1-26.

J. Seibert, 2002. HBV light version 2 User’s Manual. Environmental Assessment SLU, Sweden.

Seibert, J. and M.J.P. Vis 2012. Teaching hydrological modeling with a user-friendly catchment-runoff-model software package, Hydrology and Earth System Sciences 16: 3315-3325, doi:10.5194/hess-16-3315-2012, 2012.

I. Tromp-van Meerveld and M. Weiler. Hillslope dynamics modeled with increasing complexity. Journal of Hydrology (2008) 361, 24-40.

Links to other papers are provided on Blackboard.

Vereiste voorkennis
The student should be familiar with the subjects of the BSc course Introduction to Hydrology and Climatology (AB_1074) as detailed in the Introduction to Hydrology and Climatology (2013) course reader by M.J. Waterloo, V.E.A. Post and K. Horner.

Aanbevolen voorkennis
The student should have a good background knowledge of mathematics and physics at BSc level and have basic computer skills. In addition, the student should have basic knowledge of Earth Science, as provided by the System Earth course (AB_450067).

Doelgroep
First-year M.Sc. Hydrology students, students from Earth Sciences, Earth and Economy or Natural Sciences M.Sc. programmes.

Overige informatie
The course is open for participation to students from alternative M.Sc. programmes at the VU University Amsterdam, or from other universities. If you are a professional and wish to attend this course you can also participate on a contract basis. In both cases please do contact the course coordinator to find out if you fulfill the background knowledge requirements and for enrollment procedures.

Climate and Policy

Vakcode	AM_450188 ()
Periode	Periode 3
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. P.H. Pattberg
Examinator	dr. P.H. Pattberg
Docent(en)	dr. P.H. Pattberg
Lesmethode(n)	Werkcollege
Niveau	400

Doel vak
After studying this course, students should be able to define and explain key concepts of relevance to the climate change governance issue; understand the causes, impacts and effects of climate change and the key scientific controversies in the regime; be able to identify, explain and analyze the various policy options for mitigation and adaptation at different levels of governance; be able to understand and analyze the key political challenges in the climate change regime, the common problems facing all countries, the coalitions in the regime, the North-South, North-North, South-South, European and domestic political issues; be able to explain and assess the long-term objective, the principles, the commitments of countries and other key elements of the Climate Change Convention, the quantified commitments of developed countries, and the flexibility mechanisms under the Kyoto Protocol; be able to explain, analyze and form a judgment on the role of forestry in the climate change regime, and the various aspects of policy with respect to deforestation and land degradation; be able to define and

explain the role of market mechanisms in the climate change regime, their advantages and disadvantages, and their potential in addressing the climate change problem; be able to integrate the information learnt thus far to assess and identify possible long term solutions to the climate change problem and the research questions that emerge from a study of the climate change regime; and be able to make a judgment about which principles, policy instruments and approaches are likely to be most efficient, equitable and/or effective in addressing the climate change problem.

Inhoud vak
International policy on human-induced climate change and its mitigation is a hotly debated subject. Current (international) climate policy is the result of a complex and long-lasting negotiation process at multiple levels of governance. In this process, the science of the complex earth and climate system is closely linked to questions on the socio-economic effects of climate change, the options for global environmental governance as determined by the structure of international organizations, international economic and political relations and environmental law. These close relations between earth system research and economic/political questions make this course an interesting subject for students with a bachelor's degree in different subjects . The course includes:
- an overview of the science of climate change, its impacts (IPCC Fifth Assessment Report) uncertainties, mitigation, adaptation; - climate change policy options at multiple levels of governance; - analysis of the political challenges in climate change and the positions of different countries and actors; - assessment of the international legal instruments including the Climate Change Convention and the Kyoto Protocol, - assessment of the economics of climate change including analysing the flexible mechanisms (Emission trading, Clean Development Mechanisms, Reducing Emissions from Deforestation and Forest Degradation) and options for Post Kyoto measures; and paper discussions on a topical area of climate governance.

Onderwijsvorm
The course consists of 7-8 interactive lectures including class presentations and uses modern didactic approaches, films, and role play to help the students internalize many of the concepts and theoretical approaches developed.

Toetsvorm
The students will be examined on the basis of a paper (50%) and a closed book written examination (50%). Students must get a grade of 5.5 in each to pass in the examination.

Literatuur
Reader

Aanbevolen voorkennis
Basic knowledge of social science concepts such as governance

Doelgroep
Students with an interest in governance and policy

Climate Modelling

Vakcode	AM_450004 ()

Periode	Periode 3
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	prof. dr. H. Renssen
Examinator	prof. dr. H. Renssen
Docent(en)	prof. dr. H. Renssen, dr. M.J. Waterloo, prof. dr. A.J. Dolman, dr. D.M.V.A.P. Roche
Lesmethode(n)	Werkcollege, Computerpracticum
Niveau	400

Inhoud vak
Geological archives show convincingly that the climate system experiences variability on a wide range of time-scales. For Quaternary studies, climate variations at the following time-scales are most important: glacials-interglacials, millennia and centuries-decades. This course focuses at the mechanisms behind these variations, thereby using climate models as a tool, i.e. numerical computer models in which the dynamics of the climate system are calculated. The combination of these models and geological data will be treated extensively. The course consists of lectures giving an overview of climate models and their application (different types for different time-scales) and of discussion meetings, in which students discuss the recent literature in detail. In this way the course considers case studies for the different time-scales and deals with recent developments in climate modelling. The following two questions are central to the course: 1) What is the driving mechanism behind climate change at a particular time-scale? 2) How can we optimise the combination of climate models and geological data in order to increase our understanding of climate evolution?

Onderwijsvorm
Lectures, discussion meetings and computer exercises.

Toetsvorm
Compulsory participation in discussion meetings, computer exercises, oral presentation and written exam.

Literatuur
Lecture notes and selected papers (made available through Blackboard).

Overige informatie
The course is open for participation to students from alternative M.Sc. programmes at the VU University Amsterdam, or from other universities. If you are a professional and wish to attend this course you can also participate on a contract basis. In both cases please do contact the course coordinator to find out if you fulfill the background knowledge requirements and for enrollment procedures.

Ecohydrology

Vakcode	AM_450014 ()
Periode	Periode 2
Credits	6.0
Voertaal	Engels

Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. M.J. Waterloo
Examinator	dr. M.J. Waterloo
Lesmethode(n)	Werkcollege, Computerpracticum
Niveau	400

Doel vak
Ecohydrology is a combination of ecology (study of how organisms interact with each other and with the natural environment) and hydrology (study of how water cycles in terrestrial environments). It focuses on the role of ecosystems in the water cycle of terrestrial landscapes. The objectives of the course is to provide understanding of the functioning of ecosystems in relation to water availability and the movement of water in terrestrial ecosystems under different climates. This ecohydrological knowledge forms the basis for supporting decisions on sustainable land use from a water resources point of view. It requires fundamental theoretical knowledge on plant physiology and on the exchange of water between the soil, vegetation and the atmosphere. As such, limitations to ecosystem functioning posed by water availability in relation to evaporation and transpiration by different plant communities is a central theme in this course. In addition, the student needs to learn basic computer programming for meteorological data processing and analysis.

Inhoud vak
This course describes and discusses basic interactions between the vegetated land surface, the atmosphere and the hydrosphere. Basic questions dealt with include: what determines the broad vegetation patterns of the world, and how do these in turn determine the ecohydrological behaviour of different vegetation types? This requires understanding of primary ecohydrological processes (rainfall and cloud water interception, transpiration, soil moisture dynamics) and feedback mechanisms between the vegetation and the atmosphere as well as insight into the measurement, data analysis and modelling of these processes. The ecohydrological aspects of Dynamic Vegetation Models (DGVMs) will be discussed. Tropical and temperate deforestation impacts on catchment hydrological functioning and climate as well as desertification processes are considered. Ecohydrological processes in boreal and tundra regions, as well as in montane cloud forests will be discussed in some detail. Emphasis throughout the course is on a combination of process understanding, interpretation of experimental results, and modelling. Finally, a computer programming workshop is included to become familiar with the basics of computer programming, meteorological data processing, analysis and rainfall interception modelling.

Onderwijsvorm
The tuition consists of nine classroom lectures, a half-day student presentation session and a computer workshop (five half-days).

Toetsvorm
Written test on lecture notes and selected literature (65%), attendance of workshops (15%), and a presentation to be given on a pre-determined topic (20%).

Literatuur
Readers, scientific papers and handouts are provided during the course via Blackboard

Vereiste voorkennis
The student should be familiar with the subjects of the BSc course Introduction to Hydrology (450024) as detailed in the Introduction to Hydrology (2012) course reader by M.J. Waterloo, V.E.A. Post and K. Horner.

Aanbevolen voorkennis
The student should have a good background knowledge of mathematics and physics at BSc level and basic computer skills

Doelgroep
First-year MSc Hydrology students, students from alternative Earth Sciences, Earth and Economy or Natural Sciences MSc programmes

Overige informatie
The course is open for participation to students from alternative M.Sc. programmes at the VU University Amsterdam, or from other universities. If you are a professional and wish to attend this course you can also participate on a contract basis. In both cases please do contact the course coordinator to find out if you fulfill the background knowledge requirements and for enrollment procedures.

Environmental Remote Sensing

Vakcode	AM_450145 ()
Periode	Periode 3
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. R.A.M. de Jeu
Examinator	dr. R.A.M. de Jeu
Lesmethode(n)	Werkcollege, Computerpracticum
Niveau	400

Doel vak
This course will make the student more familiar with remote sensing and the main objectives of this course are: (i) To understand the fundamental characteristics of electromagnetic radiation and how this interacts with vegetation, soil, rock and water. (ii) To understand and master the methodology behind a large variety of remote sensing applications related to land surface observations, including a clear understanding of the limitations of these observations. (iii) To develop practical computer skills to use remote sensing products in environmental studies. During the lectures the physical basics and mathematical principles of remote sensing will be discussed. During the practical exercises we will use a suite of remote sensing-derived environmental data (i.e. geology, soil, water, and vegetation). The focus point of the course is dual; on the one side it will be focussed on the elementary knowledge and techniques and on the other site it will be focussed on the integration of several remote sensing. At the end of the course Environmental Remote Sensing the student should have:

• Knowledge of the basic principles of the electromagnetic spectrum and the operation systems for satellite and airplane remote sensing

(aerial photography, multi-spectral, and thermal scanning, microwave sensing) and the environmental applications;

• Understanding of the technology to derive reliable remote sensing products over land including vegetation products, water quality products, soil moisture, temperature and evapotranspiration.

• Knowledge of remote sensing data collection from different formats (i.e. hdf, .tif, .mat .nc) and the skills to use them in environmental studies.

• Adequate knowledge to criticize the quality of spatial data, to detect data errors, and to understand the usefulness of given datasets.

Inhoud vak
Remote sensing is a scientific technology that can be used to measure and monitor land surface processes from space. This course is designed to introduce students to:

• the fundamental characteristics of electromagnetic radiation, and;
• the interaction of electromagnetic radiation with materials such as vegetation, soil, rock, water, and the atmosphere, and;
• how this interaction can be used to study the Earth.

The lectures will focus on a large variety of remote sensing observations in different parts of the electromagnetic spectrum, each having its own application. Besides a thorough understanding of the theoretical basis, you will also learn how to use satellite data in both scientific and applied studies on scales ranging from detailed local case studies to global applications.

Onderwijsvorm
16 hours of lectures, 24 hours of practical (computer) exercises and literature study

Toetsvorm
Written Exam

Literatuur
Readers, scientific papers and handouts are provided during the course via Blackboard

Aanbevolen voorkennis
The student should have a good background knowledge of mathematics and physics at BSc level and basic knowledge of Geographical Information Systems.

Doelgroep
First-year MSc Hydrology students, students from alternative Earth Sciences, Earth and Economy or Natural Sciences MSc programmes

Extension Master Thesis Hydrology

Vakcode	AM_450151 (450003)
Credits	12.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen

Coördinator	dr. M.J. Waterloo
Examinator	dr. M.J. Waterloo

Doel vak
This subject provides the opportunity to extend the Master thesis research project (450122 or 450124) or work placement (traineeship), (450123 or 450125).

Inhoud vak
Extension of Master thesis research project or work placement (traineeship) with a volume of 12 EC (8 weeks).

Onderwijsvorm
Individual research or work placement (traineeship)

Toetsvorm
Written report integrated in master thesis. Grades are based on final Master thesis report.

Vereiste voorkennis
Having been admitted previously to the appropriate Master thesis for which this extension holds.

Overige informatie
Extension of the master thesis is an optional subject and is part of the space for elective optional subjects in the teaching programme. Extension of the master thesis is subject to the 'Work placement and thesis regulations' (stage- en scriptieregeling). As detailed written agreements between lecturer and student have been put forward already for the Master thesis, an amendment with the nature of this extension will suffice and should be forwarded prior to the start of the extension to the secretary to the examination board.

Field Course Hydrology Portugal

Vakcode	AM_1013 ()
Periode	Periode 5+6
Credits	15.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. M.J. Waterloo
Examinator	dr. M.J. Waterloo
Docent(en)	dr. B.M. van Breukelen, drs. M.M.A. Groen, dr. R.A.M. de Jeu
Lesmethode(n)	Veldwerk, Computerpracticum
Niveau	600

Doel vak
This course main objective is to instill "hydrological system thinking" in the student's mind. This is done through a combination and practical application of the earth scientific and hydrologic theory given in the period before the field course to solve hydrological questions in the field. The objectives include planning and making decisions about research strategies, learning to make relevant measurements of all the

components of the hydrological cycle (surface water, groundwater, soil moisture, vegetation, and the atmosphere) and use these measurements to make realistic qualitative and quantitative interpretations regarding the hydrological processes and conditions in the field.

The course contributes to 1) Application of Knowledge and Understanding, 2) Critical Judgement, 3) Communication and 4) Learning Focus final attainment levels of the Hydrology MSc Programme. In particular, at the end of this course the student should be able to:
• independently set up and execute a new hydrological field experiment, be able to analyse existing hydrological research projects with respect to the planning, execution and evaluation of the results,
• know the limitations of hydrological instruments and measurement techniques and how to take these into account when critically evaluating his/her own measurements
• think in a multidisciplinary way and recognise the importance of other (sub)disciplines for his/her own specialisation and combine different types of factual information, complete a report on trainee work, subject matter studied, or research carried out,
• clearly present information, both written and orally to a public of specialists from the same subject area on an independently studied topic (in English),
• read publications and reports in his/her native language and in English,
• actively and constructively participate in discussions on hydrological issues and meetings,
• work together with one or more colleagues with different scientific backgrounds,
• independently collect information on hydrological subjects and analyse, summarise and critically evaluate this information,
• recognise the continued need to keep in touch with relevant developments in his/her discipline, and is prepared to take the appropriate action to realise this,
• recognise cultural and gender-related aspects of water issues.

Inhoud vak
This course covers the practical side of hydrological research through application of geological and hydrological knowledge to solve the water balance of target areas and to study water quality issues. Students are first familiarized with the geology and hydrology of coastal areas in Portugal and with the relations between geology, land use, vegetation and water (quantity and quality). The focus then shifts to hydrogeological mapping, the collection of field measurements and their integration to develop qualitative and quantitative hydrological models for solving the water balance and to address water quality concerns (salinisation, agricultural pollution). The field work will be carried out in two areas with a different climate: a semi-arid area (Algarve) and an area with high precipitation (Aveiro region). The relation between hydrology and geology, vegetation, land use, and climate will be studied and the practical and societal aspects will be highlighted. In Aveiro, students perform an independent catchment and groundwater hydrology study. The field period is immediately followed by three weeks during which colected field data are analysed and reported in the form of an individual scientific paper.

Onderwijsvorm
The course is subdivided in three parts. Before the fieldwork a one-day preparatory workshop will be organised. The first part (2 weeks) in the Algarve has an introductory character. During the first four days there

will be an excursion devoted to (a) field observation and conceptual model development, (b) field measurements and (c) the hydrological systems in the Algarve region. The excursion is followed by a five- day field survey carried out by students in small groups and supervision limited to a few days. These surveys serve as training for the second part of the field course (4 weeks), which is near the city of Aveiro. Here, each group will be assigned a study catchment in which a hydrological observation network (surface water, ground water, meteorology, etc.) will be installed. Supervision is less intense than during the first part of the field course as students are expected to work independently and make their own decisions regarding planning and research strategy. Data processing, analysis and hydrochemical modelling are an integral part of the field course. A scientific paper-style report will be written in Amsterdam during the third and final part of the course (3 weeks).

Staff members will be present during the whole course period for supervision and for consultation by students.

Toetsvorm
- Performance and oral presentation evaluation Algarve excursion and field campaign (30%)
- Execution of field campaign Aveiro (40%)
- Publication of scientific paper Aveiro (30%)

Literatuur
J.J. De Vries and J. Schwan. Groundwater flow and geological structure of the Algarve, Portugal. VU University Amsterdam.

Boris M. van Breukelen, Michel M.A. Groen, Koos Groen, Ko van Huissteden, Richard A.M. de Jeu, Vincent E.A. Post, Jaap Schellekens and Maarten J. Waterloo (2014). Handbook for Field Hydrological Measurements. VU University Amsterdam.

Vereiste voorkennis
Admission to this field course is granted to students who have been admitted to the Hydrology MSc program. Furthermore, students must have completed the Field Course Netherlands (AM_450126) and, before mid-April, must have passed at least two of the courses Catchment Response Analysis (AM_450003), Groundwater Hydraulics (AM_450009), Hydrochemistry (AM_450052) and Unsaturated Zone and Near Surface Hydrological Processes (AM_450021).

Aanbevolen voorkennis
The student should have a good general knowledge of the subjects discussed in the basic theoretical courses M.Sc. Hydrology master, i.e. Catchment Response Analysis (AM_450003), Ecohydrology (AM_450014), Groundwater Hydraulics (AM_450009), Hydrochemistry (AM_450052), Unsaturated Zone and Near Surface Hydrological Processes (AM_450021).. Participants will need to work with ARCGIS for analysing and displaying spatial spatial data (Basics in Geographic Information Systems course (AM_450226)) and will need to be familiar with geophysical methods (geo-electrics) and other field methods as demonstrated in the Field Course Netherlands (Measurement Techniques, AM_450126).

Doelgroep
First year MSc Hydrology Programme students

Overige informatie
The course coordinator will send you an e-mail asking for information about your participation in this course in January. Besides registering for this course via the VUnet portal for this course please respond to the e-mail request of the coordinator before 31 January. The course is partly subsidized by the faculty and the students are obliged to pay for the other part of the course (travel, residence costs, etc.).

Field Course Netherlands (Measurements Techniques)

Vakcode	AM_450126 ()
Periode	Periode 5+6
Credits	3.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. J. Groen
Examinator	dr. J. Groen
Docent(en)	dr. B.M. van Breukelen, dr. J. Groen, drs. M.M.A. Groen, dr. M.J. Waterloo
Lesmethode(n)	Werkcollege, Veldwerk
Niveau	500

Doel vak
The objective of this course is to familiarize students with measurement methods and techniques that are commonly used in hydrology and environmental sciences.

At the end of the course the student should be able:
1. to select the appropriate field measurement methods and techniques for a certain hydrological question
2. to operate the equipment
3. to evaluate and interprete the results
4. to carry out the fieldwork in Portugal, which directly follows this course, and other research projects independently.

Inhoud vak
This course deals with a broad range of field measurement aspects of hydrological studies. The course starts with a one-day excursion to familiarize the participants with the geology and geomorphology of the Dinkel River watershed and practical research experience is subsequently gained through a study of the water balance and hydrochemistry of the area. This part of the course includes instructions in geophysical, geohydrological, meteorological, soil physical, and hydrochemical measurement techniques that are commonly used in surface and groundwater movement studies and in water quality investigations. Spatial data collection and processing methods are practiced through the use of portable geographic information systems. The last few days of the course are used for the analyses of data and the preparation of presentations. At this time, combining the results of different methods for estimating the water balance components solves the water balance for the area and an overview is prepared of the regional hydrochemistry. Key course subjects are installation of
hydrological equipment, rainfall, water level and discharge measurements, installation of piezometers, geodetic surveys and groundwater gradient assessment, soil and aquifer permeability

measurements (pumping test, auger hole method), automatic weather station operation, geo-electrical measurements (Schlumberger, Wenner array methods), soil moisture and tension measurements, water sampling and chemical analysis, datalogger programming, data processing and analyses, and finally, presentation techniques.

Onderwijsvorm
The 10 day course takes place at Camping Meuleman at the De Lutte, Overijssel and the direct surrounding carried out in the field. During 6 days students are in the field, receive instructions and carry out measurements in the direct surroundings of the camping and along the Dinkel River. Students work in groups of 4 to 5. In the evenings and the last two days students attend presentations by staff members on various subjects, interpret the data acquired in the field and prepare a presentation for the final evening according to a prescribed format. During the presentation every individual group member presents a part of the data and interpretations. Students have a total of 77 contact hours (days and evenings).

Toetsvorm
Students are evaluated on the basis of:
1. Individual performance in the field (33 %)
2. Individual presentation (33 %)
3. Group performance (33 %)

Literatuur
Course reader: Breukelen et al., 2009. Handbook for Field Hydrological Measurements. VU University Amsterdam. Reader is available on Blackboard.

Doelgroep
1. Dutch and foreigns students of VU Hydrology Masters program
2. Students from other universities in the Netherlands following an elecive course
3. Studenst from other European countries on Erasmus scholarships following an elective course

Overige informatie
Participants work in groups of three to four persons.

From Source to Sink: Chemical and Physical Cycles

Vakcode	AM_450146 ()
Periode	Periode 2
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. M. ter Voorde
Examinator	dr. M. ter Voorde
Docent(en)	dr. M. ter Voorde
Lesmethode(n)	Werkcollege, Computerpracticum
Niveau	400

Doel vak
After having attended this course, the student should have gained knowledge and understanding about
- The interplay of (physical) mechanisms responsible for landscape evolution
- The relative importance and the mutual interaction between these processes
- The methods to put constraints on these processes from geological data, and the strength and limitations of these methods
as well as the skills to
- Read and critically assess significant literature about these subjects
- Actively participate in (oral) discussions about these subjects
- Judge research methods applied on this subject critically on their merits and weak points
- Compare and/or combine the results of different studies.

This implies that the course is not mainly focused on acquiring new knowledge, but especially on using, integrating and reflecting on the things you may have learned before.

Inhoud vak
This course deals with the parameters regulating the production, transfer and storage of sediments and solutes from their sources to their sinks, addressing short-term and long-term landscape evolution and sustainability. It covers the linked processes of tectonics, weathering, erosional systems (fluvial, glacial, marine) and climate changes, including ‘real-world’ examples on the SE Netherlands, the Ardennes, the Pyrenees and western Scandinavia, as well as the methods to constrain these processes (e.g. provenance studies and thermochronology). Lecturers from a variety of disciplines will teach the student how to view these topics from various backgrounds.

Onderwijsvorm
Lectures, exercises, literature study. A selected set of papers will be used for a 'PhD- defense'-role play. In addition, numerical modelling of topography development will be carried out by the students.
Aantal contact-uren: 45 (inclusief tentamen)

Toetsvorm
Exam (45%), essay (20%), computer-practicum report (10%) PhD-defense-"game"(25%).

Literatuur
• Book:
Tectonic Geomorphology, D.W. Burbank and R.S. Anderson, 2nd edition, 2011. John Wiley & Sons, 320 pp.

Papers:
• Noller et al., Introduction to Quaternary geology
• Matenco et al., (2013) Quantifying the mass transfer from mountain ranges to deposition in sedimentary basins: Source to sink studies in the Danube Basin–Black Sea system (Global and Planetary Change)
• More papers, to be used for the exercises, will be made available via Blackboard

Doelgroep
Masterstudents GBL, Earth Sciences Solid Earth, Earth Sciences AEG, Earth Sciences Paleoclimate and Geo-ecosystems

Geothermal Energy

Vakcode	AM_450409 ()
Periode	Periode 5
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. M.P. Bokhorst
Examinator	dr. M.P. Bokhorst
Lesmethode(n)	Hoorcollege, Computerpracticum
Niveau	400

Doel vak

• To provide students with an overview of the current status and future outlook of geothermal exploration and production (heat/cold and electricity)
• To assess its impact in the energy-transition challenge, being a major alternative source for renewable energy.
• To provide insight into the energetical and economical aspects of different ways to supply thermal energy to buildings and processes.
• To review main categories of operational geothermal systems, the governing processes and relevant boundary conditions, linking hydrogeology to subsurface understanding
• To assess exploration concepts of geothermal prospecting and see how they can be applied to future subsurface analysis and energy supply prediction
An additional practical aim is to improve your communication and writing skills.

Inhoud vak

This course provides a comprehensive overview of existing systems that are used to supply thermal energy to buildings and/or industrial processes. The course starts with a general introduction to the history of geothermal exploration and production, what kind of geothermal systems exist, and how these are linked to particular subsurface and economical conditions. In addition it is explained what benefits of geothermal energy exist compared to other energy resources. Subsequently different aspects are explained in more detail. We will first
concentrate on the demand side, by showing how the heat and cold demand of a building can be provided by different types of energy systems and how the economical aspects of the different options relate. Later on we will focus on the hydrogeological parameters that contribute to successful geothermal systems. This is achieved through a review of several such systems, including borehole heat exchangers (closed loop systems), aquifer thermal energy storage (ATES or open loop systems) and systems for the production of deep geothermal heat for heating and/or electricity production (enhanced geothermal systems). Special emphasis is placed on the relation of subsurface conditions and operational excellence.
During the course the students are put in the role of consultants that have to choose an optimal solution for the customer. A business case is build in which different geothermal options have to be considered and compared to a conventional solution for climate control in the buildings

concerned.

Onderwijsvorm
The course uses two different methods:
Oral lessons in the form of lectures and tutorials/seminars (distributed equally) where various topics are presented by the lecturer and discussed in common with the students. Students must be aware that the content of this course is difficult to find in one-two textbooks. Therefore, understanding the handouts is essential. Our advice is to attend the oral lessons during class hours. Further students are expected to read and present material from selected papers in a short presentation and abstract.
Practical lessons: this course includes a number of practical exercises and a few case studies. Exercises and case studies will be worked out individually and in small groups and discussed in class. The rule of thumb: this is individual work, unless otherwise specifically noted.

Toetsvorm
The final mark is made up of assignments (10%), a presentation, an excursion(10) and a 1-page abstract of relevant paper(s) (10%) and case studies (70%).
The practicals and case studies will cover the topics presented during the course.

Literatuur
All materials will be digitally provided through Blackboard

Vereiste voorkennis
To facilitate a rapid in- depth study at MSc level, students are required to know in advance basic notions of hydrogeology (groundwater flow, impact of wells on hydraulic head) which were already studied during their BSc curriculum. Furthermore sufficient knowledge of mathematics and MS Office (Excel) is required.

Overige informatie
Students are on a steep learning curve of integrated techno-economic-policy concepts. Mental alertness and the flexibility are therefore essential to gaining maximum benefit from the course!
Update (Sept 10 2013): This course is not offered in 2013/2014. The next opportunity to follow this course will be spring 2015.

Global Biogeochemical Cycles

Vakcode	AM_450332 ()
Periode	Periode 4
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	prof. dr. G.R. van der Werf
Examinator	prof. dr. G.R. van der Werf
Docent(en)	dr. J. van Huissteden
Lesmethode(n)	Computerpracticum, Hoorcollege
Niveau	400

Doel vak
To achieve insight in the role of biogeochemical cycles of the Earth system in the past and present.

Inhoud vak
The course starts with an overview of the major global biogeochemical cycles and their natural and anthropogenic disturbances. The main subject is exchange of C, N, P, and S between soil, water, atmosphere, and biota on global and local scales in different climatic zones (tropics, temperate, boreal and arctic zone) and environments, e.g. forests, wetlands and marine environments. We address the relation of biogeochemical cycles with the climate system, and with the hydrological cycle. Examples of quantification of fluxes using different measurement techniques are included. Emphasis will be on evidence of large-scale global past perturbations of the biogeochemical cycles on Earth both in the past and in the present. Next to present-day anthropogenic changes, we also focus on changes in the past: changes occurring along with the Milankovitch driven glacial-interglacial oscillations , the dynamics during the millennial scale Dansgaard-Oeschger events, the Paleocene-Eocene boundary and from the Cretaceous. These illustrate the full natural range of change of the coupled biogeochemical and climate system on Earth.

Onderwijsvorm
Lectures + workshop attendance. If the number of students is too small for a full lecture programme we will work with essay assignments and workshops

Toetsvorm
Written exam, evaluation of assignments handed out during the course

Literatuur
W.H. Schlesinger: Biogeochemistry: An analysis of Global Change (Academic Press), lecture notes and literature made available during the course.

Doelgroep
MSc students Earth Sciences, Hydrology, Environment and Resource management

Groundwater Flow Modelling

Vakcode	AM_450008 ()
Periode	Periode 1
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Lesmethode(n)	Werkcollege, Computerpracticum
Niveau	400

Doel vak
The student: (1) has knowledge and insight in the terminology and the conceptual and mathematical theory of groundwater flow modelling; (2) is able to build and program basic groundwater models using the finite-

difference technique and is able to apply professional groundwater modelling software packages; (3) understands a range of professional literature, can judge its quality and (4) shows awareness of the limitations of models.

Inhoud vak
Groundwater flow models are a powerful tool to study the movement of water in the subsurface. They are so widely-used in both research and consultancy that every hydrology graduate should have the skills to understand and use groundwater flow models. This course deals with the simulation of groundwater flow using numerical methods. The topics covered include the fundamentals of numerical solution schemes (finite-difference and finite-element methods), conceptual model development, model design, model calibration, controlling error, various types of model use. Computer laboratories are an integral part of the course. Students learn to create simple models themselves (Python, spreadsheets) and build more complicated models using existing, dedicated groundwater modelling software (MODFLOW) and more generic modelling codes (FlexPDE).

Onderwijsvorm
The course consists of 12 sessions. The first part of each session (~ 1.5 hr) comprises the following elements: lecture and discussion of studied text from the course notes. Starting from session 3, each session a small team of students also presents/evaluates a studied paper. During the second part of each session (~ 2 hr) students can work individually on computer laboratories/tutorials in a computer room. Supervision is available from session 4. The remaining time (~126 hr) should be devoted to self-study including preparation study for the sessions and for the written exam and finalizing the computer assignments.

Toetsvorm
Written exam (60%) + modelling assignments (40%).

Literatuur
Course notes and online materials referred to therein:

Chiang and Kinzelbach [1998] Processing modflow: a simulation system for modeling
groundwater flow and pollution
http://www.pmwin.net/programs/prevpm/pm4/doc/pmwin41.pdf

Konikow, L.F. [2000] Use of numerical models to simulate groundwater flow and
transport. In: Environmental isotopes in the hydrological cycle – principles and
applications; Volume IV Groundwater: unsaturated and saturated zone. W.G. Mook, Editor.
IAEA Vienna. http://www-naweb.iaea.org/napc/ih/documents/global_cycle/vol%20VI/VI_Ch4.pdf

Reilly, T.E. [2001] System and boundary conceptualization in ground-water flow
simulation. Techniques of Water-Resources Investigations of the United States Geological Survey, Book 3, Applications of Hydraulics, Chapter B8
http://pubs.usgs.gov/twri/twri-3_B8/

Reilly, T.E., and A.W. Harbaugh [2004] Guidelines for evaluating ground-water flow

models. U.S. Geological Survey Scientific Investigations Report 2004-5038 http://pubs.usgs.gov/sir/2004/5038/

Additionally: paragraphs 7.2-7.4 of Domenico, P.A. & F.W. Schwartz, 1998, Physical and chemical hydrogeology, 2nd edition, Wiley.

Vereiste voorkennis
Successful participation requires a thorough background in Groundwater Hydraulics (450009). A good conceptual understanding of groundwater flow systems and its relationship with catchment hydrology is also recommended. Courses which contribute to the latter understanding are several 1st year MSc courses, notably Catchment Response Analysis (450003) and Field Course Hydrology Portugal (AM_1013).

Doelgroep
2nd year students in the Hydrology Master

Groundwater Hydraulics

Vakcode	AM_450009 ()
Periode	Periode 2
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Lesmethode(n)	Werkcollege
Niveau	400

Doel vak
The student has profound knowledge and insight in the terminology and the theory of groundwater hydraulics; in particular the mathematical notion and its physical meaning. The student can apply the theory to a range of basic/classical problems using graphical and analytical solution methods and has knowledge of the limitations of applicability of the methods used.

Onderwijsvorm
The course consists of 12 working lectures of about (~ 4 hr) each. The sessions comprise the following elements: lecture, discussion of studied theory, and desk exercises. The practicing with exercises is supervised; answers to exercises are published on blackboard after each session. The remaining time (~120 hr) should be devoted to self-study including preparation study for the sessions and for the written exam.

Aanbevolen voorkennis
Successful participation requires a good background in mathematics (notably algebra, vectors, differentiation, (partial) differential equations and integral calculus) and physics (in particular dimensional analysis and working with units) at the level of the BSc course Wis- en Natuurkunde (450073). Familiarity with basic groundwater hydrology (e.g., Inleiding Hydrologie 450024 / Inleiding Hydrologie en Klimatologie AB_1074) is also recommended.

Doelgroep
Students in the Hydrology Master

Groundwater Microbiology and Geochemistry (Geomicrobiology)

Vakcode	AM_450132 ()
Periode	Ac. Jaar (september)
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. W.F.M. Roling
Examinator	dr. W.F.M. Roling
Niveau	400

Doel vak
At the end of this interdisciplinary course, students will be able to describe and explain:
Aspects of the growth and cellular functioning of microorganisms
The role of microorganisms in nutrient cycli
Important microbial processes in polluted and pristine groundwater ecosystems
The dependency of microbial presence and activity on environmental conditions
Modern methods in microbial ecology
Students can relate the obtained knowledge to hydrology.

Inhoud vak
Theory will consist of:
Introduction to environmental microbiology:
• Microbial growth, metabolism and kinetics in relation to environmental conditions.
• Types and diversity of micro-organisms in groundwater ecosystems.
• Interactions between micro-organisms.
• Basics of molecular microbiology; overview of modern techniques in microbial ecology and biogeochemistry.
Impact of microbiological processes on hydrochemistry:
• Microbial contribution to important biogeochemical processes and nutrient cycles.
• Microbial mediated mineral dissolution and precipitation.
Degradation of organic contaminants in groundwater:
• Biodegradation, bioremediation and "natural attenuation" of pollution.

Onderwijsvorm
~90 hours of guided self-study, 70 hours for essay writing. After each of the five modules, the student and lecturer discuss the answers (~1 h per module).

Toetsvorm
Written essay (70% of final mark) on a geo-microbiological subject, linked to the interests of the student and general course content. Oral discussion on the essay and studied text (30%).

Literatuur
Madigan, M.T.,Martinko, J.M., Stahl, D.A. & Clark, D.P. (2011), Brock biology of microorganisms, 13th edition. Pearson Higher Education. ISBN: 0-321-73551-5 (about 75 euro)

Weber K.A. et al.(2006), Microorganisms pumping iron: anaerobic microbial iron oxidation and reduction. Nature Reviews in Microbiology, 4, p. 752-764.

Handout for guided self-study (via lecturer).

Intekenprocedure
The course can be started at any time during the academic year, in consultation with the coordinator

Overige informatie
This course is an elective option for master students in Hydrology. The course is also open to students in the masters Biology and Earth Sciences. Part of the content can be adapted to fit the interest and educational background of the student. Students are advised to contact the coordinator before starting.

Hydrochemistry

Vakcode	AM_450052 ()
Periode	Periode 4
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. B.M. van Breukelen
Examinator	dr. B.M. van Breukelen
Docent(en)	dr. B.M. van Breukelen
Lesmethode(n)	Werkcollege, Computerpracticum, Practicum
Niveau	400

Doel vak
To acquire a qualitative and a quantitative insight in how biogeochemical processes and the geochemical composition of the subsurface determine and change the chemical composition of water during the hydrological cycle: from precipitation, via soil, and groundwater, to surface water. To be able to interpret hydrochemical data with various methods, and to apply the numerical geochemical model PHREEQC to hydrochemical problems and interpret the simulation results. To obtain basic skills in performing laboratory analyses.

Inhoud vak
Hydro(geo)chemistry is essential for solving problems related with (ground)water quality and ecohydrology. The following topics are included: sampling and analysis of (ground)water; thermodynamics and kinetics of hydrogeochemical processes; reactive properties of hydrogeological systems; dissolution and precipitation of minerals; carbonate chemistry; weathering of silicates; cation exchange; surface complexation; redox-processes; effects of evaporation and mixing of different water types; introduction to geochemical modelling; lab and field analysis of inorganic solutes in water.

Onderwijsvorm
Working lectures (8x4 hours), Computer practical (4x4 hours), Lab practical (1x4 hours). Total contact hours is 52 hours.

Toetsvorm
Written examination of lecture-subjects (100%); evaluation of computer and laboratory practical reports (pass/no pass).

Literatuur
C.A.J. Appelo & D. Postma, 2005. Geochemistry, groundwater and pollution. 2nd edition; digital content distributed via blackboard: lecture slides, course manual, computer and lab practical manuals.

Vereiste voorkennis
inleiding in de anorganische geochemie (450022; BSc Earth Sciences) or course of similar level (to be decided by dr. B.M. van Breukelen).

Doelgroep
Hydrology Master students

Hydrological Systems and Water Management

Vakcode	AM_1012 ()
Periode	Periode 1
Credits	3.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	prof. dr. P.J. Stuijfzand
Examinator	prof. dr. P.J. Stuijfzand
Docent(en)	prof. dr. P.J. Stuijfzand
Lesmethode(n)	Werkgroep, Hoorcollege
Niveau	400

Doel vak
To provide insight into: groundwater occurrences on earth in various aquifer systems; actual and ancient recharge and discharge; methods of hydrological and hydrochemical systems analysis; groundwater monitoring and tracing; palaeogroundwater; the effects of groundwater pumping; fresh/salt relationships; and water management with emphasis on MARS (Managed Aquifer Recharge Systems), artificial recharge and river bank filtration in particular.

Inhoud vak
After introducing the concepts of porosity and permeability the hydrogeological characteristics of various regions in the world are explored, in connection with their geomorphology, lithology / sedimentology and structural geology.
Groundwater mapping techniques based on both a hydrological and hydrochemical systems analysis are presented. The dynamics in flow and chemistry of groundwater are elucidated and explained in terms of natural and man-made variations in groundwater recharge and discharge, fresh and salt water intrusion / inundation, pollution and leaching of aquifers, and climate change.
The occurrences of and how to recognize palaeogroundwater are explained. Environmental effects of groundwater pumping, like wetland degradation, land subsidence, salinization and acidification pass in review.
Methods are presented, to monitor groundwater pressure and quality, to determine the origin and age of groundwater, and to image groundwater flow using physical, chemical and isotope tracers. Various techniques are presented to manage groundwater in stressed environments. The focus is here on MARS (Managed Aquifer Recharge Systems, like artificial recharge and river bank filtration). Special attention is given to

define suitable hydro(geo)logical settings for MARS and to optimize water quality improvements during aquifer passage.

Onderwijsvorm
Lectures (~24 contact hours), practical exercises (8 hours), literature study (60 hours).

Toetsvorm
Written examination (100%)

Literatuur
a) Hydrochemistry and Hydrology of the coastal dune area of the Western Netherlands. Available via Stuyfzand (25 €).
b) Syllabus (from Blackboard).
c) Physical and Chemical Hydrogeology by Schwartz & Domenico (1998 or later): Available at Geo-VUsie (10% discount).

Additional reading (not obligatory)
• De Vries, J.J. 2002. Regional Hydrogeology. Course syllabus 2nd edition, ca. 167p. Available through Stuyfzand (10 €).
• Dufour, F.C. 2000. Groundwater in the Netherlands; facts and figures. NITG-TNO Delft, Ch.7-12.
• Davis & de Wiest 1966. Hydrogeology. Available in Library.

Vereiste voorkennis
450024 (Inleiding Hydrologie)

Aanbevolen voorkennis
Advice regarding previous courses taken: AB_450024: Inleiding Hydrologie.

Overige informatie
For questions regarding the course, besides ‘contact hours’, you can contact:
Prof. dr. Pieter Stuijfzand, room E-237, phone 020-5987.968 (VU) or 06-10945021 (mobile), pieter.stuyfzand@falw.vu.nl or pieter.stuyfzand@kwrwater.nl

Isotope Hydrology

Vakcode	AM_450148 ()
Periode	Periode 5
Credits	3.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. J. Groen
Examinator	dr. J. Groen
Docent(en)	dr. H.J. van Meerveld, dr. H.P. Broers
Lesmethode(n)	Werkcollege
Niveau	400

Doel vak
The objective of this course is to provide students with a basic understanding of the isotopic variations in water and its solutes, and fractionation and mixing processes in order to i) know which isotope

analyses could be useful for certain hydrological problems and ii) be able to read and understand literature on isotope hydrology.

At the end of this course students should be able to:
• Discuss the spatial and temporal variation in the isotopic composition of water and dissolved CO2
• Discuss the fractionation and mixing processes that determine the isotopic composition of water and solutes
• Solve simple fractionation and mixing problems
• Discuss how radioactive and stable isotopes can be used for age dating of young and old groundwater and streamflow
• Discuss how radioactive and stable isotopes can help to improve our understanding of physical processes (e.g. groundwater recharge and runoff generation mechanisms) and hydrogeochemical processes (e.g. sulphate reduction, carbonate dissolution) in the hydrological system
• Determine which isotope measurements may help solve a particular research question and have obtained a general awareness of how isotope data can be helpful in hydrological studies.

All courses in the MSc Hydrology programme contribute to certain educational Dublin Criteria that lead to the student reaching the final attainment levels defined for the Hydrology Master's. The Isotope Hydrology course contributes to:
• Knowledge and understanding – knowledge and insight into the subject is obtained through studying the theory as provided during the lectures, in the text books, and through self-study of scientific papers
• Application of knowledge and understanding – analysis of data during lectures and take-home assignments provides the skills and understanding required to process and analyse isotope data
• Critical judgment – the student is encouraged to critically judge published scientific work

Inhoud vak
After falling on the earth as precipitation, water is redistributed repeatedly in vegetation, soil, groundwater, rivers, and lakes, until it sooner or later returns to the atmosphere. During this course, water also continuously changes in solute content. The isotopes of water and its solutes are ideal tools for tracing the various hydrological processes. As such isotope hydrology is applied in scientific studies to obtain more insight in these processes, as well as for practical purposes like understanding the runoff behaviour of rivers, the effects of land-use and climate change on streamflow and recharge, groundwater exploration and management, and assessment and monitoring of water pollution.

Isotope hydrology deals mainly with the isotopes 18O, 2H and 3H in water and 3He, 4He, 13C, 14C, 15N, 34S, 37Cl, 87Sr, and 222Rn in solutes. These isotopes are diagnostic for water and solute transport and many hydrogeochemical processes. This course discusses the isotopic processes of mixing, fractionation, and decay, which lead to endless variations of isotopic ratios in nature. These patterns in space and time enable us to determine and quantify the origin and age of water, water and solute fluxes, and chemical reactions.

Onderwijsvorm
There are six lectures: 2 introductory lectures, 2 lectures on isotopes in groundwater, and 2 lectures on isotopes in surface water. There is a short lab visit during one of the lectures. Students are expected to make the assignments before the lectures as these will be discussed

during the lectures.

The number of contact hours is in the order of 25.

Toetsvorm
The grade for this course is based on the written exam (100%). The written exam is a closed book exam and consists of open ended questions, simple calculations, and interpretation of graphs.

Literatuur
Books:
• International Atomic Energy Agency and United Nations Educational, Scientific and Cultural Organization (2000) Environmental Isotopes in the Hydrological Cycle: Principles and Applications (selected chapters)
• Mook, W.G. (2005) Introduction to Isotope Hydrology. IAH series International Contributions to Hydrogeology. Taylor & Francis, London. ISBN 0415-39805-3 (selected chapters)
• Kendall C. and J.J. McDonnell (Eds.) (1998) Isotope Tracers in Catchment Hydrology, Elsevier Sci., ISBN 0-444-50155-X (selected chapters)
• Clark, I.D. & P. Fritz (1997) Environmental Isotopes in Hydrogeology. CRC Press, ISBN 1566702496. (selected chapters)

Articles:
• Broers, H.P. (2004) The spatial distribution of groundwater age for different geohydrological situations in The Netherlands: implications for groundwater quality monitoring at the regional scale. Journal of Hydrology 299: 84-106.
• Edmunds, W.M. et al. (2006) Groundwater recharge history and hydrogeochemical evolution in the Minqin Basin, North West China, Applied Geochemistry 21 (12): 2148-2170.
• McGuire and McDonnell (2006) A review and evaluation of catchment transit time modeling, Journal of Hydrology 330: 543-563.
• Vitvar et al. (2005) A Review of Isotope Applications in Catchment Hydrology, Isotopes in the Water Cycle, 151-169.

Doelgroep
M.Sc. Hydrology students

Overige informatie
Advice regarding previous courses taken: Inleiding hydrologie (bachelor course) 450024, Geochemie voor aardwetenschappers 450068 (bachelor course), and Hydrochemistry 450052 (master course Hydrology).

Master Research Project Hydrology

Vakcode	AM_1104 ()
Periode	Ac. Jaar (september)
Credits	27.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. M.J. Waterloo
Examinator	dr. M.J. Waterloo
Niveau	600

Modern Climate and Geo-ecosystems

Vakcode	AM_1124 ()
Periode	Periode 1
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. G.M. Ganssen
Examinator	dr. G.M. Ganssen
Lesmethode(n)	Excursie, Werkcollege
Niveau	400

Doel vak
In the first part the course gives an introduction of modern atmospheric and oceanic processes which form an important basics for the reconstruction of the climate of the past. Next to important basic parameters which trigger the modern circulation of both spheres, atmosphere and oceans, the main circulation paterns will be discussed together with the implications for the global climate.
In the second part the modern ocean changes and their implications for the geoecosystems will be discussed. Together, this will form the basic understanding of processes which govern changes in the geological past.

Inhoud vak
-the basic parameters and properties for atmospheric and ocean processes leading to the formation and circulation of air and water masses
- characterization of climatic regions of the world from the poles to the tropics
- special features of the climate systems like the monsoon, ENSO and NAO systems
- the effect of ocean changes on geoecosystems now and in the recent past

Onderwijsvorm
Lectures and workshops, literature reading, oral and written presentations by the students and discussing the results and quality of the presentation

Toetsvorm
Written exam after week 2 about the basics (50% of the grade)
oral and written presentation of a topic (second part of the course, 50% of the grade)

Literatuur
Lecture notes (powerpoints of the presentations by the teacher), selected papers and Ruddiman, W.F., 2013. Earth's Climate: past and future.W.H. Freeman and Company New York.

Vereiste voorkennis
Some basic knowledge of the climate system, interest in climate change

Doelgroep

Students from the geo and environmental study areas

Intekenprocedure
Subscription via BB

Modern Climate Systems

Vakcode	AM_450185 ()
Periode	Ac. Jaar (september), Periode 1
Credits	3.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. G.M. Ganssen
Examinator	dr. G.M. Ganssen
Docent(en)	dr. G.M. Ganssen
Lesmethode(n)	Werkcollege
Niveau	400

Doel vak
To understand the physical and chemical processes that control atmosphere and ocean.

Inhoud vak
This introductory course gives a (short) overview into the physical and chemical processes driving the atmosphere and the ocean. Knowledge of the modern climate processes forms the basis for understanding Climate Change today and in the past.

Knowledge to gain about:
- the basic parameters and properties of atmospheric and ocean examples
- processes leading to the formation and circulation of air and water masses
- characterization of climatic regions of the world from the poles to the tropics
- special features of the climate systems like the monsoon, ENSO and NAO systems

Onderwijsvorm
Lectures and workshops, literature reading.

Toetsvorm
Written exam

Literatuur
Lecture notes, selected papers and Ruddiman, W.F., 2008. Earth's Climate: past and future.W.H. Freeman and Company New York.

Modern Geo-ecosystems

Vakcode	AM_450313 ()
Periode	Ac. Jaar (september), Periode 1
Credits	3.0
Voertaal	Engels

Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. G.M. Ganssen
Examinator	dr. G.M. Ganssen
Docent(en)	dr. G.M. Ganssen
Lesmethode(n)	Werkcollege, Excursie
Niveau	400

Doel vak
To understand the interactions between the geo-, bio-, hydro- and atmosphere in a selected number of modern terrestrial and marine geo-ecosystems. Special focus is given on both the natural processes and the human impact during the Anthropocene.

Inhoud vak
Anthropogenic changes to the Earth’s climate, land, oceans and biosphere are now so huge and rapid that the concept of a new geological epoch defined by the action of humans, the Anthropocene, is widely and seriously debated.

Knowledge to gain about:
- scale, magnitude and significance of modern environmental change especially in relation to Earth’s geological history.

Onderwijsvorm
Lectures, literature study, student presentations (45 minutes, teaching eachother by lecturing) and essay writing.

Toetsvorm
Oral presentation, written essay

Literatuur
Lecture notes, selected papers.

Reflection Seismic for Geologists

Vakcode	AM_450170 ()
Periode	Periode 4
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. B.P. Zoetemeijer
Examinator	dr. B.P. Zoetemeijer
Docent(en)	dr. B.P. Zoetemeijer
Lesmethode(n)	Werkcollege, Computerpracticum

Doel vak
The participant is expected to collect sufficient understanding of the fundamentals and the limitations of the applications of reflection seismology as a tool to predict the structure and geology in the shallow to deeper (100's to 1000's of metres) subsurface. The aim is to derive the evolution of sedimentary basins and underlying crust by using seismostratigraphic and structural interpretation of seismic lines. In particular, the participant will learn:

the application of technical and methodological principles of reflection seismology to real situations;
the basic principles linking geology and reflection seismology, including an introduction to petrophysics;
seismic workstation skills for seismic interpretation, and
how to extract reliable information on sequence stratigraphy and structure from seismic reflection and well log data.

Inhoud vak

Assuming a basic knowledge of the principles of reflection seismology, this course provides a modular programme with hands-on experience on interpreting seismic lines and integrating data from well logs, principles and interpretation of reflection seismic data and geology. Special attention will be paid to pitfalls in data acquisition, processing and interpretation. The course will use in part similar methodologies used in hydrocarbon exploration and development. The course is constructed in 5 parts:

Part 1 Introduction to seismics. The introduction will cover the technical and methodological broadband principles of reflection seismology. Note that this section will build on already existing Applied Geophysics course knowledge;

Part 2 Introduction to interpretation. Students will learn how to interpret basic geological features, such as strata relationships, faults and folds as well as the reliability of seismic interpretation at various scales;

Part 3 Seismic sequence stratigraphy. Learning seismostratigraphy will mean in practice how to extract stratigraphic, sedimentological and basin evolution information from seismic data. This information is used as a tool in exploration and basin analysis to derive regional analysis of sedimentary basin-fills with a view towards constructing models for gross lithology prediction. It is recommended that students remind themselves the principles and methodology of sequence stratigraphy, already acquired during their BSc courses;

Part 4 Seismic structural interpretation. This section will provide students with the knowledge of interpreting deformation structures at various scales;

Part 5 Interpretation on workstation. This section gives the students the opportunity to work on case studies by using standard workstation methodologies for seismic interpretation. Students will learn how to handle, visualize and interpret 2D and 3D seismic data using a standard industrial software package;

Part 6 Integrating wells with seismics for seismostratigraphy, deriving basin evolution. The section will give students the chance to start from reflection seismic and correlative well interpretation to derive the evolution of sedimentary basins at local and regional scale.;

Part 7 Advanced seismic interpretation This section will give students the opportunity to work with advanced methodologies of seismic interpretation specific for petroleum exploration.

Onderwijsvorm

The course uses two different methods:

Oral lessons, where the lecturer presents various topics. Students must be aware that the content of this course is difficult to find in one-two textbooks. Therefore, understanding the handouts is essential. Our advice is to attend the oral lessons during class hours.

Practical lesson; the bulk of this course is made up by a large number of practical exercises and a few case studies. You will have to hand in at the end of the course a part of these for evaluation purposes, as noted by the staff. Make sure you understand which are

those exercises and case studies needed for evaluation. The thumb rule: this is individual work, unless otherwise specifically noted.

Toetsvorm
The final mark is made up by 50% the practical exercises and case studies handed in at the end of the course and 50% the final examination. The practical exercises and case studies must be handed in no later than one day prior to the final examination. The exam will cover the topics presented during course. It is typically organized in blocks of questions from every part of the course AND 2 - 5 data sets (seismic lines) which you will be asked to interpret in terms of specific issues.

Literatuur
All materials will be digitally provided through Blackboard.

Overige informatie
Teaching staff: John Verbeek

Scientific Writing in English

Vakcode	AM_471023 ()
Periode	Ac. Jaar (september)
Credits	3.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	M. van den Hoorn
Lesmethode(n)	Werkgroep
Niveau	400

Doel vak
The aim of this course is to provide Master's students with the essential linguistic know-how for writing a scientific article in English that is well organized idiomatically and stylistically appropriate and grammatically correct.
At the end of the course students
- know how to structure a scientific article;
- know what the information elements are in parts of their scientific article;
- know how to produce clear and well-structured texts on complex subjects;
- know how to cite sources effectively;
- know how to write well-structured and coherent paragraphs;
- know how to construct effective sentences;
- know what collocations are and how to use them appropriately;
- know how to adopt the right style (formal style, cohesive style, conciseness, hedging)
- know how to avoid the pitfalls of English grammar;
- know how to use punctuation marks correctly;
- know what their own strengths and weaknesses are in writing;
- know how to give effective peer feedback.

Final texts may contain occasional spelling, grammatical or word choice errors, but these will not distract from the general effectiveness of the text.

Inhoud vak
The course will start with a general introduction to scientific writing in English. Taking a top-down approach, we will then analyse the structure of a scientific article in more detail. As we examine each section of an article, we will peel back the layers and discover how paragraphs are structured, what tools are available to ensure coherence within and among paragraphs, how to write effective and grammatically correct sentences and how to choose words carefully and use them effectively.

Topics addressed during the course include the following:
- Structuring a scientific article
- Considering reading strategies: who is your readership? How do they read your text? What do they expect? How does that affect your writing?
- Writing well-structured and coherent paragraphs
- Composing effective sentences (sophisticated word order, information distribution).
- Arguing convincingly – avoiding logical fallacies
- Academic tone and style: hedging – why, how, where?
- Using the passive effectively
- Understanding grammar (tenses, word order, etc.)
- Understanding punctuation
- Referring to sources: summarising, paraphrasing, quoting (how and when?)
- Avoiding plagiarism
- Vocabulary development: using appropriate vocabulary and collocations

Onderwijsvorm
Scientific Writing in English is an eight-week course and consists of 4 contact hours during the first week and 2 contact hours a week for the rest of the course. Students are required to spend at least 6 to 8 hours of homework per week. They will work through a phased series of exercises that conclude with the requirement to write several text parts (Introduction, Methods or Results section, Discussion and Abstract). Feedback on the writing assignments is given by the course teacher and by peers.

Toetsvorm
Students will receive the three course credits when they meet the following requirements:
- Students hand in three writing assignments (Introduction, Methods or Results, Discussion) and get a pass mark for all writing assignments;
- Students provide elaborate peer feedback;
- Students attend all sessions;
- Students are well prepared for each session (i.e. do all homework assignments);
- Students actively participate in class;
- Students do not plagiarise or self-plagiarise.

Literatuur
Effective Scientific Writing: An Advanced Learner's guide to Better English (A. Bolt & W. Bruins, ISBN 978 90 8659 6171). VU bookstore: €27.95.

Intekenprocedure

General enrollment information:
The registration for this course consists of two steps:
(1) Students should register for the course through VUnet;
(2) After the VUnet registration, students should register for a specific Blackboard group.

Each master programme has one or more designated groups. This designated group offers the best option for the student in terms of study load and schedule. Each semester, one or more open/general groups take place (with a minimum of 18 participants), for which students may register instead of the designated group for their master programme, for example in case of schedule difficulties or because they hacve to re-sit the course. Students are advised to consult their schedule carefully, since overlap may occur.

Important: Each group has a minimum of 18 and maximum of 24 participants, so students should register on time to ensure a place in one of the (designated) groups.

Please note that even though the VUnet registration is a requirement for the course, only a Blackboard registration in the appropriate group will give you access to the sessions of the course. You will be expected to attend all sessions in the group for which you have a Blackboard registration.

Instructions for Blackboard enrollment:
- An overview of all SWiE groups for the academic year 2014 - 2015 is available under "Course Documents".
- On rooster.vu.nl, the schedule for each group (time and room) can be found under the course name (also available under "Course Documents").
- Based on the group overview and the schedule, please check which one of the designated groups for your master programme you prefer (please check if the course does not coincide with other (elective) courses).
- Go to "Group enroll" and select your master programme.
- Enroll in the group you have selected.

Sustainable Land Management

Vakcode	AM_1015 ()
Periode	Ac. Jaar (september), Periode 3
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	drs. W.A.M. Tuijp
Examinator	drs. W.A.M. Tuijp
Docent(en)	dr. W.R.S. Critchley
Lesmethode(n)	Werkcollege
Niveau	400

Doel vak
What are the enabling and limiting factors to sustainable land management? How can smallholder farmers in the developing world adapt to climate change? What can farmers in developing countries – and especially Africa – do to improve their food security? Can organic agriculture help feeding the world? Are biofuels the solution for our

energy needs of tomorrow?
These and many other questions will be discussed during this interdisciplinary course. Its main focus is on what can be done about the problems of soil erosion and land degradation, and their relevance to climate change and poverty reduction. "Sustainable Land Management" is a new approach that involves both people and technical issues. The course spans a wide range of topics, including environmental problems, history of approaches, conservation technologies in the field, indigenous knowledge, working with local people, and skills in research and development in the tropics. There is a combination of theory and practice, with a strong emphasis on illustrated case studies from over 20 countries.

Inhoud vak
Environmental degradation and rural poverty: processes and impact. History of conservation: from failed approaches to new concepts in rural development; principles and practices of Sustainable Land Management (SLM). Agriculture in Development. SLM technologies: humid areas/dry areas. International environmental protocols and their impact on rural development programs. Socio-economic factors including population/land tenure/gender/incentives/marketing and labeling. Energy and biofuels; biodiversity, genetic modification and organic production. ICTs in rural development. Indigenous knowledge and local innovation, Participatory learning and action, including research methodology).

Onderwijsvorm
Interactive lectures (about 38 hours in total) with illustrated case studies supplemented by group work activities; conducted and examined in English.

Toetsvorm
One topic will be chosen by each student for a paper of 3.000 words based on further reading (50% mark). There will also be a final examination (50% mark).

Literatuur
"Where the land is greener" WOCAT, Eds Liniger and Critchley, plus additional supporting literature.
https://www.wocat.net/en/knowledge-base/documentation-analysis/global-overview-book.html

Doelgroep
Aimed at Master’s students with environmental and developmental interests: especially those with some geography/earth science/hydrological/biological/ecological/environmental background, but social scientists can also benefit from this course.

Overige informatie
Comments from former students:
"I think this course gives a good overview and helps students with a non environmental background to understand essential issues."
"Good job, keep on going! Continue to be part of the ERM programme."
"Whereas other courses focus on scientific dimension of environmental problems SLM is also about the human dimension of environmental solutions. It is one of the few courses that gives a positive perspective for practical solutions. Whereas other courses try to inject "knowledge" theoretical problems and solutions."
"The course was a great launch pad for my thesis research. "
"This should be a specialization track! Sustainable Land Management 2

would be very interesting and give students more time to learn about the topics."

For more information please contact Wendelien Tuyp (w.a.m.tuijp@vu.nl)

Transport Processes in Groundwater

Vakcode	AM_450131 ()
Periode	Periode 1
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Docent(en)	dr. B.M. van Breukelen
Lesmethode(n)	Hoorcollege, Computerpracticum
Niveau	500

Doel vak
The aim of this course is that participants: (1) develop basic understanding of theory of reactive transport in groundwater systems and its applications (2) are able to do transport calculations for simple problems (3) acquire some experience with modelling of (more complicated) transport problems using computer software.

Inhoud vak
Hydrogeology is to a large extent concerned with flow of water in the subsurface (courses Groundwater Hydraulics and Groundwater Flow Modelling). However, numerous practical and scientific applications of groundwater hydrology involve transport of solutes (dissolved chemical species) or heat in groundwater systems, rather than the flow of groundwater itself. Examples are contaminant hydrogeology, tracer hydrogeology, sea-water intrusion, subsurface energy applications and geothermal conditions. Knowledge of transport processes and conversion processes (reactions) is of paramount importance to hydrogeologists.
Topics that will be addressed in the course are:
Fundamental transport processes: advection, diffusion, dispersion and first-order reaction (sorption and retardation) in 1, 2 and 3 dimensions. Basic behaviour of the individual and combined processes. Numerical approaches, methods and codes. The role of uncertainty in process parameters. Implications of discrepancies in scale of measurement and process scale.

Onderwijsvorm
Working lectures, desk exercises, exercises with computer codes and case studies, a modelling or literature assignment

Toetsvorm
Written exam (70%) + assignments during the course (30%)

Literatuur
Course notes; Domenico, P.A. & F.W. Schwartz, 1998, Physical and chemical hydrogeology, 2nd edition, Wiley.; paper(s) assigned via Blackboard

Aanbevolen voorkennis

Some background in partial differential equations and related math such as taught in bachelor course Wis- en Natuurkunde voor Aardwetenschappers (AB_450073) is strongly recommended. Knowledge of Groundwater Hydraulics (AM_450009), Groundwater Flow Modelling (AM_450008) and Hydrochemistry (AM_450052) is useful, but not essential.

Unsaturated Zone and Near Surface Hydrological Processes

Vakcode	AM_450021 ()
Periode	Periode 4
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. M.J. Waterloo
Examinator	dr. M.J. Waterloo
Docent(en)	dr. H.J. van Meerveld
Lesmethode(n)	Computerpracticum, Werkcollege
Niveau	400

Doel vak
The main objective of this course is to provide basic insight into the hydrological processes operating within the unsaturated zone as a whole, and near the surface in particular. This hydrological knowledge forms the basis for determining recharge rates, plant available water, runoff ratios, etc. It requires fundamental theoretical and practical knowledge on soil properties and the physics of soil water movement.

At the end of this course students should be able to:
• Discuss soil characteristics in relation to soil water movement and storage
• Discuss the processes that determine the storage and movement of water in the unsaturated zone, and how this affects and is affected by other hydrological processes
• Describe the various measurement techniques to determine the storage and movement of water in and through the unsaturated zone
• Produce a simple hydrological model to analyse and describe the movement of water through the unsaturated zone and analyse how this is affected by soil properties
• Discuss the objectives, advantages and limitations of hydrological models for the unsaturated zone
• Present the results of a small hydrological modelling study in a clear and concise way
• Have obtained an awareness of how vegetation and land management affect soil erosion and water quality

The Unsaturated Zone and Near-Surface Hydrological Processes course contributes to the final attainment levels defined for the hydrology master's:
• Knowledge and understanding – knowledge and insight into the subject is obtained through studying the theory as provided during the lectures, in the text books, and through self-study of scientific papers
• Application of knowledge and understanding – analysis of data during lectures and workshops provides the skills and understanding required to process and analyse hydrological data
• Critical judgment – the student is encouraged to critically judge

his/her work during the modelling workshops and the preparation of the report
• Communication – the presentation of the modelling results (structure, readability, etc.), as well as oral communication and discussion skills during the lectures

Inhoud vak
The course focuses on the following topics: hydraulic potential theory; soil water retention aspects; measurement techniques for soil water content and matric potential; stationary and non- stationary unsaturated flow (hydraulics); infiltration during conditions of ponding; determining saturated and unsaturated soil hydraulic conductivities; macropore vs. matrix flow; surface erosion processes (splash, wash and rill erosion) and governing factors.

Onderwijsvorm
The course consists of ten lectures and three computer practicals. The number of contact hours is in the order of 40.

Toetsvorm
Written examination.

Literatuur
Books:
• Koorevaar et al. (1983) Elements of Soil Physics. Elsevier, ISBN 0-444-42242-0 (selected chapters)
• Hillel D (1998) Environmental Soil Physics. Academic Press, ISBN 0-12-348525-8 (selected chapters)
• Morgan, R.P.C. (2005) Soil Erosion and Conservation, 3rd edition. Blackwell Publishing, Oxford, ISBN 978-1405117814 (selected chapters)

Articles:
• Anderson, A., Weiler, M., Alila, Y., and Hudson, R. O., 2009 Dye staining and excavation of a lateral preferential flow network, Hydrology and Earth Systems Science 13, 935-944.
• Bengtsson, L., R.K. Saxena, and Z. Dressie (1987) Soil water movement estimated from isotope tracers, Hydrological Sciences Journal 32:497-520.
• Horton, J.H. and R.H. Hawkins (1965) Flow Path of Rain From the Soil Surface to the Water Table, Soil Science. 100(6):377-383.
• Hoogmoed, W. B., and J. Bouma, (1980) A Simulation Model for Predicting Infiltration into Cracked Clay Soil, Soil Sci. Soc. Am. J. 44: 458–461
• Tricker, A.S. (1981), Spatial and temporal patterns of infiltration, Journal of Hydrology 49: 261-277.
• Western and Grayson. 2000. Soil Moisture and Runoff Processes at Tarrawarra, in: Grayson and Bloschl, Spatial Patterns in Catchment Hydrology: Observations and Modelling, Cambridge University Press.

Vereiste voorkennis
Participants are advised to follow the course on Groundwater Hydraulics (450009) first.

Doelgroep
First-year M.Sc. Hydrology students, students from Earth Sciences, Earth and Economy or Natural Sciences M.Sc. programmes.

Water and Policy

Vakcode	AM_468023 ()
Periode	Periode 1
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	prof. dr. J.C.J.H. Aerts
Examinator	prof. dr. J.C.J.H. Aerts
Docent(en)	prof. dr. J.C.J.H. Aerts, drs. R. Lasage, prof. dr. ir. R. Brouwer, dr. D. Huitema, dr. H. de Moel, prof. dr. J. Gupta
Lesmethode(n)	Hoorcollege, Computerpracticum
Niveau	400

Doel vak
The objective of this course is to understand how water related processes such as floods and droughts influence our society and what role water management plays in addressing and tackling these issues. This course aims to provide students a multi-disciplinary understanding of water management, including the physical dimensions of the hydrological cycle and coastal proceses,
the policy, law and long term trends such as climate change and land use change. It puts emphasis on the uncertainty of future trends and how risk management methods can be helpful for water managers for dealing with these uncertainties.

Key goals for students to reach at the end of the course are:
• To understand the complexity of various water related issues (e.g. scarcity, floods, and droughts) and to assess the economic and social impacts
• To learn what kind of measures can be taken to alleviate water related problems and what kind of positive and negative effect these measures have on different users.
• To be able to systematically approach a complex and integrated water related issue and properly interpret data and information about this issue.

Inhoud vak
Water managers see themselves confronted with a continuous stream of increasingly credible scientific information on the potential magnitude of population growth, economic activities and climate change that increase the risk related to the earth hydrological system. It is expected that floods and droughts will increasingly affect societies and economies and new approaches in water management are needed to deal with these challenges. Furthermore, developing adequate water policies that can be used in practice is a difficult issue and is the result of a complex and long-lasting process from the national through to the local level. In this process, the science of the water- and socio-economic systems can play an important role by supplying policy makers with answers on e.g. the socio-economic effects of floods and droughts. Uncertainty in future trends further puts new challenges to water management and risk based techniques can be helpful in dealing with these uncertainties. Finally, water management increasingly needs to cooperate with spatial planners, especially in large cities, to address increasing risk from storm surges and sea level rise.

Onderwijsvorm
This course consists of several sessions going into different subjects related to water management. These sessions will consist of lectures by the professors with interactive discussion; two practical assignments, and student presentations. Apart from these sessions, you will team up in pairs of two students to write papers on water related issues and adaptation in cities, which will be peer-reviewed by other students.
Activity Hours
1 Attending and contributing to sessions (12 times 3 hrs) 36 hours
2 Readings associated with lectures 28 hours
4 Paper: literature review (32 hours), writing (24 hours), peer review (8 hours) 64 hours
5 Exam preparation 40 hours
TOTAL 168 hours

Toetsvorm
Written exam (50%), essay (40%) and peer-review (10%)

Literatuur
The literature for this course consists of various academic papers and chapters. These papers will be published 3 days before the lecture

Doelgroep
MSc students Environment and Resource Management (ERM), MSc Hydrology; Earth Sciences and Economics(ESE).