Karlsruhe Institute of Technology

Module Handbook

Water Science & Engineering (MSc)

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KIT-Department of Civil Engineering, Geo and Environmental Sciences






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1 Study Guide

This module handbook is the relevant document describing the structure and the contents of the master's degree program *Water Science & Engineering*, and thus provides helpful information and guidance for planning the studies. The degree program and its subjects and modules are described in detail, thus providing the necessary information for planning an interdisciplinary course of studies tailored to each student's personal interests and needs.

The first section Study Guide specifies the organization of the degree program and further formalities in addition to the general examination regulations (ER/SPO). For example, the assignments of modules to the compulsory and elective subjects are specified. Another key function of the module handbook is the collection of module descriptions (Section 2), which provide information on the requirements and recommendations for the modules.

1.1 Objectives of the Degree Program

The master's degree program *Water Science & Engineering* offers an interdisciplinary, research-oriented education at the interface of water-related engineering and natural sciences. Graduates are able to develop strategies and technical solutions for sustainable water resources management. This includes an efficient use of limited water resources, implementing increasing requirements for the protection of water bodies, handling of hydro-meteorological extreme events, and mitigating the impacts of global change on the water cycle and related material cycles. Graduates are qualified for a responsible position in planning offices and engineering companies, industrial enterprises, public authorities, international development cooperation, and research and development. They acquire qualifications that allow pursuing doctoral studies.

Graduates acquire broad and in-depth knowledge of water-related scientific and engineering fundamentals, extending their prior knowledge acquired during the bachelor degree program. The lectures and classes on 'Advanced Fundamentals' are complemented by lectures and classes on engineering and scientific methods as well as interdisciplinary competencies ('Cross Cutting Methods & Competencies'). Graduates are able to transform their theoretical knowledge into quantitative approaches for the balancing of systems and to solve them analytically and numerically. They can precisely describe relevant circumstances in the environment, and represent specialized solutions to both experts as well as laypersons in an understandable form. Through practical exercises in laboratories, in computer pools or field work, graduates acquire the ability to apply methods on their own in specific contexts. They have sound knowledge of the analysis of time- and space- related data, the design of experiments, and the assessment of uncertainties of measurement and model results. The methods and practices used can be reflected and adapted to changing conditions.

The specialization area is made up of the four profiles 'Water Technologies & Urban Water Cycle', 'Fluid Mechanics & Hydraulic Engineering', 'Environmental System Dynamics & Management', and 'Water Resources Engineering', which are oriented towards current job profiles. Within the 'Profile Studies', graduates acquire the competence to link the fundamental and advanced knowledge with engineering applications in their selected field. They are thus able to transfer their expertise into the development of innovative technologies and management concepts. Supplementary modules also offer the possibility to complement the specialization with skills from neighboring scientific and engineering disciplines.

The competence to work out structured solutions is further promoted by an interdisciplinary 'Study Project', in which the theoretical knowledge and skills are applied to deal with a specific problem.

Graduates in *Water Science & Engineering* have a broad knowledge and in-depth expertise in their subject, comprehensive methodological competences, and a sound understanding of complex interactions in environmental systems. They are able to apply a range of analytical, experimental, technical and planning methods to fulfill their tasks in solving water-related problems in consideration of social and economic criteria. They deal autonomously with the current state of research and are able to analyze complex problems and select adequate methods for target-oriented solutions. As teaching is predominantly in English and students collaborate in international teams, graduates are also able to communicate their research findings in an international framework.

1.2 Structure and Courses

The degree program *Water Science & Engineering* comprises 120 credit points (CP) and is structured in the subjects (Fig. 1)

- Advanced Fundamentals, AF (27 CP)
- Cross-Cutting Methods & Competencies, CC (12 CP)
- Specialization: Profile Studies, P (36 CP)
  - PA Water Technologies & Urban Water Cycle
  - PB Fluid Mechanics & Hydraulic Engineering
  - PC Environmental System Dynamics & Management
  - PD Water Resources Engineering
- Study Project, SP111 (15 CP)
- Master's Thesis, MT199 (30 CP).

Advanced Fundamentals (AF)

In this subject, 'Advanced Fundamentals' of water-related engineering and sciences are taught. All students attend a lecture series on 'Modeling of Water and Environmental Systems' (Table 1). They further choose four out of seven subject-specific modules – according to their fields of interest and their selected specialization (cf. 'Profile Studies').

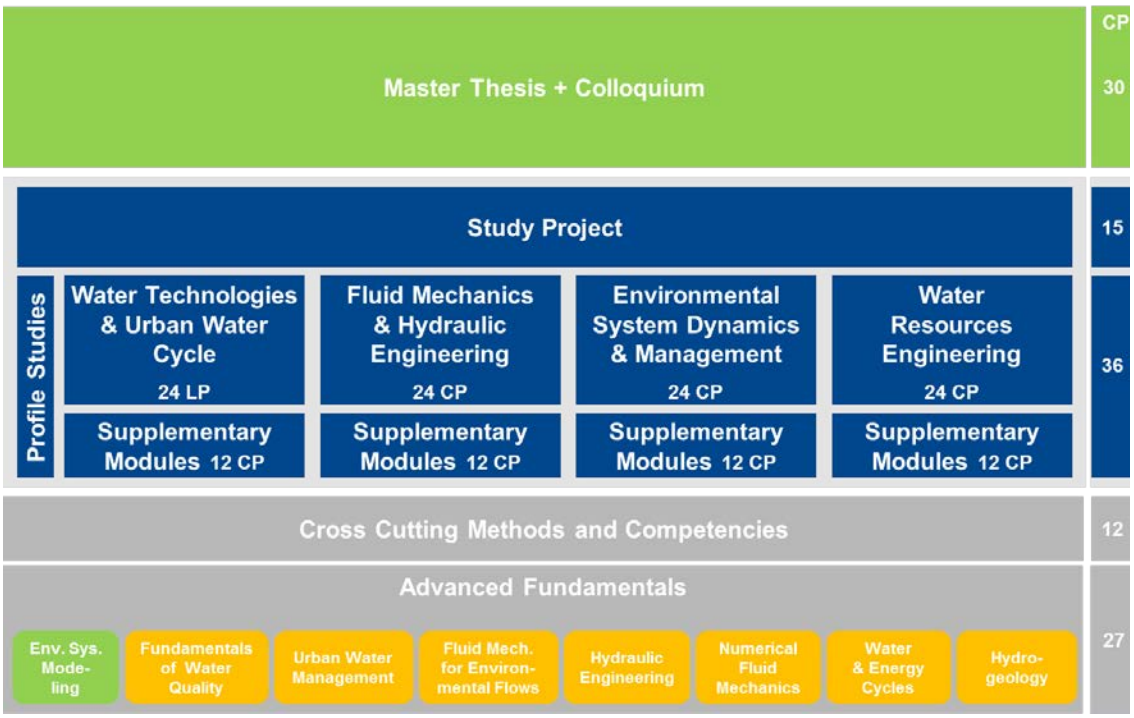

Fig. 1: Structure of the master's degree program *Water Science & Engineering.*

Cross-Cutting Methods & Competencies (CC)

The scientific education is complemented by a comprehensive education in interdisciplinary methods and technical skills. Students select modules of at least 12 CP in total from the options in Table 2. In line with the international orientation of the program, language courses of up to 6 CP can be taken in the module 'Language Skills CC949'.

Profile Studies (P)

The MSc *Water Science & Engineering* provides opportunity for specialization within three areas of expertise in the sectoral profiles A - C. In addition, an education of generalists in water engineering is possible in the cross-sectoral profile D. Students choose one of the four profiles at the beginning of their studies. The choice of a profile is effected with the online registration for the first profile-specific exam.

Within the profile, modules of 36 CP have to be completed, of which at least 24 CP need to be covered by modules specific to the chosen profile. In addition, further modules of the profile or 'Supplementary Modules' are chosen.

Profile A: Water Technologies & Urban Water Cycle (PA)

The focus of this profile is on innovative technologies for the treatment of drinking water and wastewater, as well as the sustainable design of urban and decentralized water systems. This includes biological, chemical and physical processes of water treatment, as

well as planning and dimensioning of infrastructure and facilities for water supply and wastewater disposal. In addition to the basic and advanced technological principles and applications, energy efficiency and economics are important aspects.

Students in the profile 'Water Technologies & Urban Water' select modules of at least 24 CP in total from the options in Table 3, and additional 'Supplementary Modules' if desired.

Profile B: Fluid Mechanics & Hydraulic Engineering (PB)

The aim of this profile is to deepen advanced hydrodynamic principles, and amplify their application for flows in the environment as well as for planning and dimensioning of hydraulic structures for water management. Emphasis is on substantiated education in physical and numerical modeling. Profile A focuses in application is on the preservation and regeneration of the structural quality of water bodies, under consideration of ecological aspects.

Students in the profile 'Fluid Mechanics & Hydraulic Engineering' select modules of at least 24 CP in total from the options in Table 4, and additional 'Supplementary Modules' if desired.

Profile C: Environmental System Dynamics & Management (PC)

This profile focuses on the processes of the water cycle in terrestrial systems and related matter and energy cycles. It also includes all aspects of integrated management of river basins, such as management strategies for the protection of surface and ground waters, the prediction of water-related extreme events, and the development of prevention and mitigation measures.

Students in the profile 'Environmental System Dynamics & Management' select modules of at least 24 CP in total from the options in Table 5, and additional 'Supplementary Modules' if desired.

Profile D: Water Resources Engineering (PD)

This profile aims at training generalists as the individual specialization. Consequently, it features a diversification into the topics of the three profiles A – C.

Students in the profile 'Water Resources Engineering' select modules of at least 24 CP in total from the options in Tables 3 to 5, and additional 'Supplementary Modules' if desired. At least one module from each of the three profiles A to C has to be chosen.

Supplementary Modules (P/SM)

The individual specialization within the profile studies can be complemented by electives in order to individualize the profile studies. All subject-specific modules of the program for

which an examination has not already been taken can be chosen as ‘Supplementary Modules’.

These could thus be further modules from the chosen profile, from other profiles, or from the subjects AF and CC (with the exception of the module ‘Language Skills CC949’). Alternatively, modules from cognate disciplines at KIT can be chosen, such as Geoecology, Meteorology, Civil Engineering (e. g. Geotechnical Engineering), Applied Geosciences (e. g. Engineering Geology), or Chemical and Process Engineering. Examples of possible ‘Supplementary Modules’ from other disciplines are listed in Table 6.

The choice of ‘Supplementary Modules’ should be coordinated with the mentor. The mentor advises on suitable modules for the chosen orientation. Choosing modules not listed in Tables 1 to 6 in this handbook requires the compilation of an individual curriculum for the student, which needs to be approved by the mentor and registered with the administration (Studierendenservice).

Study Project

Students carry out an interdisciplinary ‘Study Project’, for which 15 CP are credited. The project prepares students for independent scientific working and writing, and introduces skills in project management. The topics for the ‘Study Projects’ should be especially located at the interfaces between the water-research disciplines of the KIT. In addition to the competence of combining approaches from different fields, they acquire abilities for team work and critical evaluation of results in the context of the project.

It is highly recommended to have acquired the necessary subject-specific and interdisciplinary competencies needed to work on the ‘Study Project’ beforehand.

The assignment of a research topic, supervision and evaluation of the ‘Study Project’ is carried out by a full-time faculty member of the KIT-Department of Civil Engineering, Geo and Environmental Sciences or of the KIT-Department of Chemical and Process Engineering, who offers courses in the master’s program. Students look for a supervisor from the field they are interested in. In exceptional cases and at request of the student, the spokesperson of the study program ensures that a topic is assigned within a four week period.

Master’s Thesis

The ‘Master’s Thesis’ is an independent scientific study and includes the theoretical and/or experimental work on a complex problem. Students deal with the current state of research and apply the expertise and scientific methods acquired during the studies. They can document, discuss and evaluate the obtained results. Furthermore, they are able to present and defend the essential findings. The topic of the ‘Master’s Thesis’ depends on the subject area that is chosen for the thesis.

Generally, the ‘Master’s Thesis’ is written during the 4th semester. In order to be admitted to the ‘Master’s Thesis’, students must have successfully completed modules of at least

42 CP in the master's degree program *Water Science & Engineering.* It is highly recommended to have acquired the necessary subject-specific and interdisciplinary competencies needed to work on the ‘Master’s Thesis’ beforehand.

Students look for a supervisor and a further examiner from the field they are interested in. The research topic for the ‘Master’s Thesis’ is assigned by the supervisor, who has to be a professor, a habilitated faculty member, or an entitled research associate, and who ha has to be a member of the KIT-Department of Civil Engineering, Geo and Environmental Sciences, or of the KIT-Department of Chemical and Process Engineering. Generally, the supervisor and a second examiner evaluate the thesis. For the assignment of the research topic, the interests of the student can be taken into account. In exceptional cases, the assignment of a research topic for the ‘Master’s Thesis’ is arranged by the chairperson of the examination board.

The ‘Master’s Thesis’ is registered with the administration (Studierendenservice). The processing time is six months. The ‘Master’s Thesis’ can be written in English or German, and has to be completed with a presentation within one month after submission of the thesis. The presentation is part of the examination and is considered within the evaluation.

Generic Qualifications

Generic qualifications are taught along with the modules, especially in the subjects ‘Cross Cutting Methods & Competencies’ and ‘Study Project’.

Additional Subjects

Students may voluntarily acquire further credit points (up to 30 CP) from the entire choice of courses at KIT. These are not taken into account for the final grade of the degree, but are recognized as ‘Additional Subjects’ in the *Transcript of Records* and, on request, in the *Master of Science Certificate*. The choice as ‘Additional Subject’ has to be declared upon registration for an exam with the ‘Studierendenservice’.

1.3 Overview on Subjects and Modules

The subjects are individually shaped by the selection of modules within the given options. Each module consists of one or more related lectures and/or classes, and is completed by taking one or more exams. The scope of each module is given by credit points (CP) that are credited when the module is successfully completed.

In addition to this module handbook, the university calendar and possibly announcements of the institutes inform about further details, for example on times and places of lectures and classes.

Personal Curriculum & Mentoring

The many options within the program require students to compile their own personal curricula. The modules should be chosen carefully. Students therefore receive advice from a mentor, whom they choose at the beginning of their studies. Mentors have to be professor, associate professor, or a habilitated faculty member at the KIT-Department of Civil Engineering, Geo and Environmental Sciences or at the KIT-Department of Chemical and Process Engineering, and have to be involved in the master's degree program *Water Science & Engineering.* In the case that students want to take modules other than those described in Tables 1 to 6 in this module handbook, the individual curriculum needs to be approved by the mentor and registered with the administration (Studierendenservice).

Example curricula for the four profiles are given in Section 1.4.

Table 1: Modules AF - Advanced Fundamentals

Students have to render 27 CP in the subject 'Advanced Fundamentals'. The module 'Modeling of Water and Environmental Systems (AF101)' is compulsory for all students. Four of the seven modules AF201 to AF801 are chosen additionally. It is advisable to include the basic modules for the chosen profile; which are:

- for Profile A : AF201 and AF301
- for Profile B: AF401, AF501 and AF601
- for Profile C: AF701 and AF801

Module Names	Course Names	CP	HPW	Type	W/S	LC	G/E
AF101: Modeling of Water and Environmental Systems *		3	2	L	W	uLC	E
AF201: Fundamentals of Water Quality	Fundamentals of Water Quality and Exercises	6	3	L/T	W	wE	E
AF301: Urban Water Infrastructure and Management		6	4	L/T	S	wE + uLC	E
AF401: Advanced Fluid Mechanics		6	4	L/T	S	wE	E
AF501: Numerical Fluid Mechanics	Numerical Fluid Mechanics I	6	4	L/T	W	wE	E
AF601: Hydraulic Engineering	Multiphase Flow in Hydraulic Engineering	6	2	L/T	S	wE	E
	Design of Hydraulic Structures		2	L/T	S		
AF701: Water and Energy Cycles	Water and Energy Cycles in Hydrological Systems: Processes, Predictions and Management	6	4	L/T	W	oE	E
AF801: Hydrogeology	General and Applied Hydrogeology	6	2	L/T	W	wE	E
	Field Methods in Hydrogeology		1	L/T	S		

*compulsory

Abbreviations:

CP	credit points
HPW	class hours per week
W	winter semester
S	summer semester
G	German
E	English
G/E	teaching language: German documents: English
LC	learning control
wE	written examination
oE	oral examination
EoT	examination of other type
uLC	ungraded learning control

Type of courses:

L	lecture
T	tutorial
S	seminar
P	practical training
E	excursion

Table 2: Modules CC - Cross-Cutting Methods & Competencies

Students choose modules of at least 12 CP from the range CC471 to CC949.

Module Names	Course Names	CP	HPW	Type	W/S	LC	G/E
CC471: Experiments in Fluid Mechanics/ Strömungsmechanische Experimente	Experimental Methods and Physical Experiments/Experimentelle Methoden und physikalische Experimente	6	4	L/T	S	oE + uLC	G/E
CC771: Data Analysis and Environmental Monitoring/ Datenanalyse und Umweltmonitoring	Geostatistics	9	4	L/T	S	oE	E
	Analysis of Hydrological Time Series/ Analyse hydrologischer Zeitreihen		2	L/T	W		G
CC371: Water Ecology	Applied Ecology and Water Quality	6	3	L/S	S	EoT + uLC	E
	Field Training Water Quality		1	T	S		
CC921: Instrumental Analysis	Instrumental Analysis	6	2	L	S	oE + uLC	E
	Organic Trace Analysis of Aqueous Samples		2	P	S		
CC922: Microbial Diversity/ Mikrobielle Diversität	Microbial Diversity/ Mikrobielle Diversität	9	2	L	W	wE + EoT	G
	Laboratory Course: Microbial Diversity/ Praktikum: Mikrobielle Diversität		6	P			
CC907: Principles of Sustainable Water Management		3	2	S	W	EoT	E
CC791: Infrastructure Planning – Socio-economic & Ecological Aspects		6	4	L/S/T	W	wE + uLC	E
CC792: Environmental Communication/ Umweltkommunikation		6	2	S	W	EoT + uLC	G
CC772: Introduction to Matlab		3	2	L/T	W	uLC	E
CC911: Probability and Statistics		3	2	L	S	oE	E
CC931: Remote Sensing and Positioning	Terrestrial & Satellite Positioning	6	2	L/T	W	oE	E
	Remote Sensing & Geo Information Systems		2	L/T	W		E

Table 2 continued: Modules CC - Cross-Cutting Methods & Competencies

Module Names	Course Names	CP	HPW	Type	W/S	LC	G/E
CC933: Introduction to GIS for Students of Natural, Engineering and Geo Sciences/ Einführung in GIS für Studierende natur-, ingenieur- und geowissenschaftlicher Fachrichtungen		6	4	L/T	W	wE + uLC	G
CC935: Spatial Data Infrastructures and Web Services/ Geodateninfrastrukturen und Webdienste		4	3	L/T	S	oE + uLC	G
CC912: Numerical Mathematics for Informatics and Engineering/ Numerische Mathematik für die Fachrichtungen Informatik und Ingenieurwesen		6	3	L/T	S	wE	G
CC949: Language Skills *(not subject specific)		2-6		S	W S	uLC	

Table 3: Modules PA - Water Technologies & Urban Water Cycle

Students in this profile choose modules of 36 CP in total, of which at least 24 CP have to be from the range PA221 to PA982, and additional 'Supplementary Modules' if desired:

Module Names	Course Names	CP	HPW	Type	W/S	LC	G/E
PA221: Water Technology		6	3	L/T	W	oE	E
PA222: Membrane Technologies and Excursions	Membrane Technologies in Water Treatment	6	2	L	W	oE + uLC	E
	Waste Water Disposal and Drinking Water Supply – Introduction and Excursions		1	L/E	S		
PA982: Applied Microbiology	Microbiology for Engineers	8	2	L	S	oE	E
	Environmental Biotechnology		2	L	W	oE	E
PA223: Practical Course in Water Technology		4	2	L/P	S	EoT	E
PA321: Process Engineering in Wastewater Treatment	Municipal Wastewater Treatment	6	2	L/T	W	wE	E
	International Sanitary Engineering		2	L/T	W		
PA322: Wastewater and Storm Water Treatment	Process Technologies in Water Supply, Storm Water Treatment and Wastewater Disposal	6	4	L/T	S	EoT	E
PA323: Industrial Water Management	Cleaner Production	6	2	L/T	S	oE + uLC	E
	Adapted Technologies		2	L/T	W		
PA621: Water Distribution Systems/ Wasserverteilungssysteme		6	4	L/T	W	oE + uLC	G/E
PA224: Biofilm Systems		4	2	L	S	oE	E

Table 4: Modules PB - Fluid Mechanics & Hydraulic Engineering

Students in this profile choose modules of 36 CP in total, of which at least 24 CP have to be from the range PB421 to PB661, and additional 'Supplementary Modules' if desired:

Module Names	Course Names	CP	HPW	6	W/S	LC	G/E
PB421: Environmental Fluid Mechanics		6	4	L/T	W	wE	E
PB521: Analysis of Turbulent Flows	Fluid Mechanics of Turbulent Flows	6	2	L	S	oE	E
	Modeling of Turbulent Flows – RANS and LES		2	L	W		
PB522: Advanced Computational Fluid Mechanics	Numerical Fluid Mechanics II	6	2	L/T	S	oE	E
	Parallel Programming Techniques for Engineering Problems		2	L/T	S	wE	
PB431: Technical Hydraulics/ Technische Hydraulik	Steady and Unsteady Operation of Hydraulic Systems/Stationärer und instationärer Betrieb von hydraulischen Anlagen	6	4	L/T	S	wE	G
PB641: Experimental Hydraulics and Measuring Techniques/Versuchswesen und Strömungsmesstechnik	Flow Measuring Techniques/ Strömungsmesstechnik	6	2	L/T	W	oE	G
	Experimental Hydraulics/ Wasserbauliches Versuchswesen II		2	L/T	W	EoT	G
PB631: Hydraulic Structures	Groundwater Flow around Structures	6	2	L/T	S	oE	E
	Interaction Flow-Hydraulic Structures/ Wechselwirkung Strömung – Wasserbauwerke		2	L/T	W	oE	G
PB651: Numerical Flow Modeling in Hydraulic Engineering/ Numerische Strömungsmodellierung im Wasserbau		6	4	L/T	W	oE	G
PB653: Hydro Power Engineering/ Energiewasserbau		6	4	L/T	S	oE	G/E
PB655: Waterway Engineering/ Verkehrswasserbau		6	4	L/T	S	oE + uLC	G/E

Table 4 continued: Modules PB - Fluid Mechanics & Hydraulic Engineering

Module Names	Course Names	CP	HPW	6	W/S	LC	G/E
PB633: Flow and Sediment Dynamics in Rivers/ Fließgewässer-dynamik und Feststofftransport	Flow Behavior of Rivers	6	2	L/T	S	oE + uLC	E
	Morphodynamics/ Morphodynamik		2	L/T	S		G/E
PB661: Water Resources Management – Feasibility Study/ Projektstudium: Wasserwirtschaftliche Planungen	Project Studies in Water Resources Management/ Projektstudium: Wasserwirtschaftliche Planungen	6	4	L/T	W	EoT	G

Table 5: Modules PC - Environmental System Dynamics & Management

Students in this profile choose modules of 36 CP in total, of which at least 24 CP have to be from the range the range PC741 to PC986, and additional 'Supplementary Modules' if desired:

Module Names	Course Names	CP	HPW	Type	W/S	LC	G/E
PC741: Thermodynamics of Environmental Systems		6	4	L/T	W	EoT	E
PC721: Management of Water Resources and River Basins		6	4	L/T	S	EoT	E
PC725: Transport and Transformation of Contaminants in Hydrological Systems		9	5	L/T	S	oE + uLC	E
PC731: Experimental Hydrology	Hydrological Measurements in Environmental Systems	9	4	L/T/P	S	EoT	E
	Isotope Hydrology		2	L/T			
PC341: River Basin Modeling	Mass Fluxes in River Basins	6	2	L	S	EoT	E
	Modeling Mass Fluxes in River Basins		2	T	W		
PC761: Aquatic Ecosystems/ Gewässerlandschaften		6	4	L/S/E	W	EoT + uLC	G
PC762: Protection and Use of Riverine Systems		6	3	S/E	S	EoT + uLC	E
PC561: Groundwater Management	Groundwater Hydraulics	6	2	L/T	S	oE	E
	Numerical Groundwater Modeling		2	T	W	EoT	
PC821: Hydrogeology: Field and Laboratory Methods/ Hydrogeologie: Gelände- und Labormethoden	Preparatory Seminar/ Vorbereitendes Seminar	6	1	S	S	EoT	G
	Field and Laboratory Excercises/ Gelände- und Laborübungen		2	T	S		
PC831: Hydrogeology: Groundwater Modeling/ Hydrogeologie - Grundwassermodellierung		6	4	L/T	W	EoT	G

Table 5 continued: Modules PC - Environmental System Dynamics & Management

Module Names	Course Names	CP	HPW	Type	W/S		LC	G/E
PC841: Karst and Isotopes/ Karst und Isotope	Karst Hydrogeology/ Karsthydrogeologie	6	2	L/T/E	W		wE	G
	Field Trip Karst Hydrogeology/ Exkursion zur Karsthydrogeologie		3 days			S		
	Isotope Methods in Hydrogeology/ Isotopenmethoden in der Hydrogeologie		2 days			S		
PC986: Management of River and Wetland Ecosystems/ Management von Fluss- und Auenökosystemen	Ecology of Rivers and Wetlands / Fluss- und Auenökologie	6	2	L	W		wE	G
	Ecosystem Management/ Ökosystemmanagement		2	S		S	EoT	

Table 6: Additional Supplementary Modules

'Supplementary Modules' can be chosen to complement the modules in each profile. These can be selected from the subject-specific modules AF, CC, PA, PB, and PC listed in Tables 1 to 5.

In addition, the following modules are eligible as 'Supplementary Module's without formal approval. It is still advised to coordinate the choice of 'Supplementary Modules' with the mentor.

Module Names	Course Names	CP	HPW	Type	W/S	LC	G/E
Engineering Geology							
SM879: Thermal Use of Groundwater		3	2	L/T	W	oE	E
Geotechnics							
SM961: Earthwork and Embankment Dams/ Erdbau und Erddammbau	Grundlagen des Erd- und Dammbaus	6	2	L/T	W	EoT	G
	Erddammbau		2	L/T	S		
SM962: Environmental Geotechnics/ Umweltgeotechnik	Übertagedeponien	6	2	L/T	W	oE	G
	Altlasten - Untersuchung, Bewertung und Sanierung		2	L	W	oE	
Meteorology							
SM971: General Meteorology/ Allgemeine Meteorologie	Allgemeine Meteorologie	6	3	L	W	uLC	G
	Übungen zur Allgemeinen Meteorologie		2	T			
SM972: Meteorological Hazards and Climate Change/ Meteorologische Naturgefahren und Klimawandel	Meteorologische Naturgefahren	6	2	L	S	oE	G
	Advanced Seminar IPCC Assessment Report/Hauptseminar IPCC Sachstand-bericht		2	S	W	EoT	G/E
SM973: Applied Meteorology: Turbulent Transport/ Angewandte Meteo-rologie: Turbulente Ausbreitung	Turbulente Ausbreitung	6	2	L	S	oE + uLC	G
	Übungen zu Turbulente Ausbreitung		1	T			

1.4 Example Curricula

This section contains example curricula for each of the four profiles. In addition to these examples, many other combinations are possible. Students are guided in the choice of modules by their mentors.

Abbreviations

Subjects

AF	Advanced Fundamentals
CC	Cross-Cutting Methods & Competencies
P	Profile Studies
PA	Profile A
PB	Profile B
PC	Profile C
PD	Profile D
P/SM	Profile Studies/Supplementary Modules
SP	Study Project
MT	Master's Thesis

General Information

CP	credit points
HPW	class hours per week
LC	learning control
G	German
E	English
G/E	teaching language: German/documents: English

Type of Courses

L	lecture
T	tutorial
S	seminar
P	practical training
E	excursion

Learning Controls

wE	written examination
oE	oral examination
EoT	examination of other type
uLC	ungraded learning control

Example Curriculum PA: Water Technologies & Urban Water Cycle

1st Semester (winter semester)

Hours per week: 18; credit points: 30; exams: 4 (ungraded LC are not counted)

Subject	Module	Title	CP	HPW	Type	LC	G/E
AF	AF101	Modeling of Water and Environmental Systems	3	2	V	uLC	E
	AF201	Fundamentals of Water Quality	6	3	L/T	wE	E
	AF701	Water and Energy Cycles	6	4	L/T	oE	E
CC	CC772	Introduction to Matlab	3	2	L/T	uLC	E
P	PA221	Water Technology	6	3	L/T	oE	E
	PA621	Water Distribution Systems/ Wasserverteilungssysteme	6	4	L/T	oE + uLC	G/E

2nd Semester (summer semester)

Hours per week: 19; credit points: 29; exams: 5 (ungraded LC are not counted)

Subject	Module	Title	CP	HPW	Type	LC	G/E
AF	AF301	Urban Water Infrastructure and Management	6	4	L/T	wE + uLC	E
	AF401	Advanced Fluid Mechanics	6	4	L/T	wE	E
CC	CC921	Instrumental Analysis	6	4	L/P	oE + uLC	E
	CC911	Probability and Statistics	3	2	L	oE	E
P	PA222	Membrane Technologies and Excursions	2	1	E	uLC	E
	PA322	Wastewater and Storm Water Treatment	6	4	L/T	EoT	E

3rd Semester (winter semester)

Hours per week: 10 + Study Project (3 months); credit points: 31; exams: 4

Subject	Module	Title	CP	HPW	Type	LC	G/E
P	PA222	Membrane Technologies and Excursions	4	2	L	oE	E
	PA321	Process Engineering in Wastewater Treatment	6	4	L/T	wE	E
P/SM	PB421	Environmental Fluid Mechanics	6	4	L/T	wE	E
SP	SP111	Study Project	15	-	-	EoT	E

4th Semester (summer semester)

Master's Thesis (6 months); credit points: 30; exams: 1

Example Curriculum PB: Fluid Mechanics & Hydraulic Engineering

1st Semester (summer semester)

Hours per week: 18; credit points: 27; exams: 4 (ungraded LC are not counted)

Subject	Module	Title	CP	HPW	Type	LC	G/E
AF	AF401	Advanced Fluid Mechanics	6	4	L/T	wE	E
	AF601	Hydraulic Engineering	6	4	L/T	wE	E
CC	CC471	Experiments in Fluid Mechanics/ Strömungsmechanische Experimente	6	4	L/T	oE	G/E
P	PB521	Analysis of Turbulent Flows	3	2	L	-	E
	PB633	Flow and Sediment Dynamics in Rivers/Fließgewässerdynamik und Feststofftransport	6	4	L/T	oE	G/E

2nd Semester (winter semester)

Hours per week: 20; credit points: 30; exams: 5 (ungraded LC are not counted)

Subject	Module	Title	CP	HPW	Type	LC	G/E
AF	AF101	Modeling of Water and Environmental Systems	3	2	L	uLC	E
	AF701	Water and Energy Cycles	6	4	L/T	oE	E
	AF501	Numerical Fluid Mechanics	6	4	L/T	wE	E
P	PB521	Analysis of Turbulent Flows	3	2	L	oE	E
	PB421	Environmental Fluid Mechanics	6	4	L/T	wE	E
	PB651	Numerische Strömungsmodellierung im Wasserbau	6	4	L/T	oE	G

3rd Semester (summer semester)

Hours per week: 12 + Study Project (3 months); credit points: 33; exams: 4

Subject	Module	Title	CP	HPW	Type	LC	G/E
P/SM	PB431	Technische Hydraulik	6	4	L/T	wE	G
	PC721	Management of Water Resources and River Basins	6	4	L/T	EoT	E
CC	CC371	Water Ecology	6	4	L/S/T	EoT + uLC	E
SP	SP111	Study Project	15	-	-	EoT	E

4th Semester (winter semester)

Master's Thesis (6 months); credit points: 30; exams: 1

Example Curriculum PC: Environmental System Dynamics & Management

1st Semester (winter semester)

Hours per week: 19; credit points: 31; exams: 3 (ungraded LC are not counted)

Subject	Module	Title	CP	HPW	Type	LC	G/E
AF	AF101	Modeling of Water and Environmental Systems	3	2	L	uLC	E
	AF201	Fundamentals of Water Quality	6	3	L/T	wE	E
	AF701	Water and Energy Cycles	6	4	L/T	oE	E
	AF801	Hydrogeology	4	2	L/T	-	E
CC	CC771	Data Analysis and Environmental Monitoring/Datenanalyse und Umweltmonitoring	3	2	L/T	-	G
	CC772	Introduction to Matlab	3	2	L/T	uLC	E
	CC931	Remote Sensing and Positioning	6	4	L/T	oE	E

2nd Semester (summer semester)

Hours per week: 18; credit points: 29; exams: 5 (ungraded LC are not counted)

Subject	Module	Title	CP	HPW	Type	LC	G/E
AF	AF401	Advanced Fluid Mechanics	6	4	L/T	wE	E
	AF801	Hydrogeology	2	1	L/T	wE	E
P	PC561	Groundwater Management	3	2	L/T	oE	E
	PC725	Transport and Transformation of Contaminants in Hydrological Systems	9	5	L/T	oE + uLC	E
	PC731	Experimental Hydrology	9	6	L/T	EoT	E

3rd Semester (winter semester)

Hours per week: 10 + Study Project (3 months); credit points: 30; exams: 4

Subject	Module	Title	CP	HPW	Type	LC	G/E
P	PC561	Groundwater Management	3	2	T	EoT	E
	PC741	Thermodynamics of Environmental Systems	6	4	L/T	EoT	E
P/SM	PB421	Environmental Fluid Mechanics	6	4	L/T	wE	E
SP	SP111	Study Project	15	-	-	EoT	E

4th Semester (summer semester)

Master's Thesis (6 months); credit points: 30; exams: 1

Example Curriculum PD: Water Resources Engineering

1st Semester (winter semester)

Hours per week: 19; credit points: 31; exams: 3 (ungraded LC are not counted)

Subject	Module	Title	CP	HPW	Type	LC	G/E
AF	AF101	Modeling of Water and Environmental Systems	3	2	L	uLC	E
	AF201	Fundamentals of Water Quality	6	3	L/T	wE	E
	AF801	Hydrogeology	4	2	L/T	-	E
CC	CC931	Remote Sensing and Positioning	6	4	L/T	oE	E
	CC949	Language Skills: German language course	6	4	L/T	uLC	G
P	PA323	Industrial Water Management	3	2	L/T	uLC	E
P/SM	CC907	Principles of Sustainable Water Management	3	2	S	EoT	E

2nd Semester (summer semester)

Hours per week: 18; credit points: 29; exams: 6 (ungraded LC are not counted)

Subject	Module	Title	CP	HPW	Type	LC	G/E
AF	AF301	Urban Water Infrastructure and Management	6	4	L/T	wE	E
	AF601	Hydraulic Engineering	6	4	L/T	wE	E
	AF801	Hydrogeology	2	1	L/T	wE	E
P	PB653	Hydro Power Engineering/ Energiewasserbau	6	4	L/T	oE	G/E
	PC762	Protection and Use of Riverine Systems	6	3	S/E	EoT + uLC	E
	PA323	Industrial Water Management	3	2	L/T	oE	E

3rd Semester (winter semester)

Hours per week: 10 + Study Project (3 months); credit points: 30; exams: 4

Subject	Module	Title	CP	HPW	Type	LC	G/E
P	PA321	Process Engineering in Wastewater Treatment	6	4	L/T	wE	E
	PA621	Wasserverteilungssysteme/Water Distribution Systems	6	4	L/T	oE + uLC	G/E
P/SM	SM879	Thermal Use of Groundwater	3	2	L/T	oE	E
SP	SP111	Study Project	15	-	-	EoT	E

4th Semester (summer semester)

Master's Thesis (6 months); credit points: 30; exams: 1

1.5 Exams and Learning Controls

The successful completion of modules is checked with learning controls, which can be graded or ungraded. Graded learnings controls are written exams (wE), oral exams (oE), or examinations of other type (EoT). Ungraded learning controls (uLC) are course-related performances in written, oral or practical form.

Registration

The students must register for learning controls at the online student portal. The examiners can define deadlines and requirements for the registration.

Upon registration, students have to declare the assignment of the respective module to a subject, as far as options exist.

Cancellation

Students may cancel their registration for written exams (wE) without giving reasons until the examination questions are handed out. When canceling oral examinations (oE), the examiner must be informed at least three working days prior to the examination date.

Canceling of examinations of other type (EoT) as well as of ungraded learning controls (uLC) is possible up to the rendering of the respective performance or the first part of the performance. The submission of a written work (report, homework or similar) or the beginning of an oral exam (presentation, colloquium or similar) counts as rendering the performance. If deadlines are set, a cancelation can only be made in advance.

A later cancelation or withdrawal must be justified by valid grounds, and requires submitting a written declaration to the examination committee immediately.

Retake of exams

A failed examination (wE, oE, EoT) can be repeated once in the same form. If the retake of a written exam is failed again, an oral examination takes place, in which at best the grade *Passed* can be achieved. Failed exams have to be retaken by the end of the examination period of the semester after the following semester.

Ungraded learning controls (uLC) may be repeated several times.

1.6 Recognition of Accomplishments

Recognition of External Credits

The recognition of external accomplishments, for example credits obtained in other master's programs or at other universities, have to be requested by the respective recognition form of the examination committee. The respective lecturers confirm if the accomplish-

ments are equivalent to their modules in the curriculum. Accomplishments that are not equivalent to modules in the curriculum can be accredited if the acquired competences contribute to the qualification goals of the master's program. If necessary, an individual curriculum has to be compiled and approved by the mentor.

The examination committee decides on which accomplishments are accredited and which parts of the curriculum may be replaced. The form for recognition has to be submitted to the study advisor, who will transfer it to the examination committee and the "Studierendenservice".

Accomplishments Obtained Outside of the Higher Education System

Accomplishments made outside of the higher education system, as for example vocational training, can be accredited if the acquired competences contribute to the qualification goals of the master's program. Recognition is requested with the respective form of the examination committee.

The examination committee verifies to which extent the acquired knowledge and capabilities can be recognized, and which parts of the program they can replace. At maximum, 50 % of the university education can be replaced. The form for recognition has to be submitted to the study advisor, who will transfer it to the examination committee and the "Studierendenservice".

1.7 Special Circumstances

Students with physical challenges or chronic illness

Students with physical challenges or chronic illness can get compensation for possible disadvantages ("Nachteilsausgleich"). They may be granted preferential access to place-limited courses, modification of the sequence of courses according to their needs, or modifications of the form or conditions of exams. Students should contact the study advisor in order to prepare a request in writing to the exam committee including supporting documents. The exam committee decides on the modified details of the courses and exams, respectively, in accordance with the student and the examiners.

Examples of possible compensations of disadvantages:

- Modified form of exams, for instance oral exams instead of written exams, and vice versa
- Conducting exams in a separate room
- Allowing necessary utilities and assistance, e.g. sign language interpreter
- Additional breaks during time-limited exams
- Extension of the periods between exams

Maternity Leave, Parental Leave and Family Commitments

Maternity leave according to the legal regulations interrupts any time period set by the examination regulations. Parental leave and family commitments, for example time needed for caring of family members, can also be handled with modified time periods for exams. In all these cases, a request in writing including supporting documents is to be submitted to the exams committee via the study advisor.

In the case of parental leave, the exam committee has to be informed in writing at least four weeks in advance about the duration of the parental leave. If the conditions are met that would allow parental leave for employees, the student is informed about the modified time periods for exams.

The time period for the master's thesis cannot be interrupted due to parental leave or family commitments. In these cases, the registration of the master's thesis is cancelled, and a new topic will be assigned to the student.

1.8 Forthcoming Changes

Wintersemester 2017/18

Module PA222

The lecture „Membrane Technologies in Water Treatment“ will be given in 2017/18 for the last time in winter semester. Starting from summer semester 2019, the lecture will be given in summer.

2 Module Descriptions

2.1 Explanation of Module Codes

The module codes are combinations of letters and a three-digit number. The letters encode the subject in which the module is allocated. The first digit reflects the unit of organization that is responsible for the module, while the other two digits are also encoding the subject. The coding scheme is given in Table 7.

Table 7: Scheme for module codes

Letters: Subject	First Digit: Unit of Organization	Digits 2 - 3: Subject
AF. Advanced Fundamentals CC: Cross-Cutting Methods and Competencies PA: Profile A PB: Profile B PC: Profile C SM: Supplementary Modules (Profile)	1: General 2: Water Chemistry 3: Sanitary Engineering 4: Environmental Fluid Mechanics 5: Numerical Fluid Mechanics 6: Hydraulic Engineering 7: Hydrology 8: Applied Geosciences	01 – 20: AF 21 – 70: P 71 – 99: CC
	9: Other units of organization	01 – 49: CC 50 – 79: SM 80 – 89: P 90 – 99 AF

2.2 Advanced Fundamentals

Modeling of Water and Environmental Systems

Module Code	AF101
Responsible Lecturer	**Prof. Dr.-Ing. Erwin Zehe**
Level	4
ECTS Credits	3
Study Program	MSc *Water Science & Engineering*, compulsory module in the subject 'Advanced Fundamentals'
Instruction Language	English
Duration	1 semester
Module Frequency	Each winter semester
Learning Controls/Exams	Ungraded learning control in form of a task-led homework (written test on knowledge and comprehension questions about the contents of the lecture series of about 10 pages)
Special Features of the Exam	None
Grade	The module is not graded (pass/fail).
Requirements	None
Recommendations	None
Conditions	None
Learning Outcomes	Students can explain approaches to model environmental systems in different water-related disciplines. Based on this, they are able to explain common approaches and methods of environmental system modeling, and to name and evaluate the respective advantages, disadvantages, ranges of applicability and inherent limitations. Students can explain universal challenges of modeling and are able to select adequate model concepts for given water-related tasks.

Courses	Title	Type	HPW	Semester		Lecturer
	Modeling of Water and Environmental Systems	L	2	W		E. Zehe, O. Eiff, M. Uhlmann, F. Nestmann, S. Fuchs, H. Horn, U. Mohrlok
Content	This lecture series comprises individual lectures on environmental systems modeling from a broad range of water-related disciplines (e. g. flood forecasting, contaminant transport, fluid-particle interaction, water quality, or hydraulic design). The commonalities and differences of the modeling approaches are discussed with respect to their conceptual approach, mathematical formulation and numerical scheme. Spatial and temporal scales as well as discretization of the various models are compared and discussed. Based on this broad range of examples, universal challenges of modeling are illustrated: Intrinsic uncertainties, adequate selection of numerical schemes, calibration and validation, adequate model choice.					
Workload	Attendance time: 30 h Preparation/follow-up: 30 h Learning control (questionnaire): 30 h					
Literature/ Learning Materials						

Fundamentals of Water Quality

Module Code	AF201
Responsible Lecturer	**Dr. Gudrun Abbt-Braun**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the subject 'Advanced Fundamentals'
Instruction Language	English
Duration	1 semester
Module Frequency	Each winter semester
Learning Controls/Exams	Written exam, 90 min
Special Features of the Exam	None
Grade	Grade of the written exam
Requirements	None
Recommendations	None
Conditions	None
Learning Outcomes	Students can explain the relationships behind the occurrence of geogenic and anthropogenic compounds and microorganisms in the hydrological cycle. They are able to select adequate methods for the analysis of water constituents and microorganisms in water samples. They are familiar with the associated calculations, and they can compare and interpret the obtained data. They know how to apply different methods, how to analyze relationships and how to critically assess water quality analyses.

Courses	Title	Type	HPW	Semester		Lecturer
	Fundamentals of Water Quality and exercises	L/T	2/1	W		G. Abbt-Braun
Content	Various types of water, legislations, analytical definitions, analytical quality, sampling methods, quick test methods, field investigations, organoleptic determinations, general investigations, optical characterization (turbidity, color, UV, Lambert-Beer`s law, photometry), titrations, acid-base-systems, buffering, main inorganic compounds (anions, cations, occurrence, ion chromatography, titration, complexometry, flame photometry, atomic spectroscopy), heavy metals and metalloids (occurrence and main methods for determination), organic compounds and organic micropollutants (occurrence, thin layer chromatography, high performance liquid chromatography, infrared spectroscopy, gas chromatography), water-specific sum parameters (DOC, AOX, COD, BOD), radioactivity, microbiology.					
Workload	Attendance time: 45 h Preparation/follow-up: 65 h Examination + exam preparation: 70 h					
Literature/ Learning Materials	Harris, D. C. (2010): Quantitative Chemical Analysis. W. H. Freeman and Company, New York. Crittenden J. C. et al. (2005): Water Treatment – Principles and Design, Wiley & Sons, Hoboken. Patnaik P. (2010), Handbook of Environmental Analysis: Chemical Pollutants in Air, Water, Soil, and Solid Wastes. CRC Press. Wilderer, P. (2011). Treatise on Water Science, Four-Volume Set, 1st Edition; Volume 3: Aquatic Chemistry and Biology. Elsevier, Oxford. Leture notes in ILIAS					

Urban Water Infrastructure and Management

Module Code	AF301
Responsible Lecturer	**Dr.-Ing. Stephan Fuchs**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the subject 'Advanced Fundamentals' MSc *Civil Engineering*
Instruction Language	English
Duration	1 semester
Module Frequency	Each summer semester
Learning Controls/Exams	Written exam, 60 min, and an ungraded learning control (lab report / project report of 8 to 15 pages)
Special Features of the Exam	None
Grade	Grade of the written exam
Requirements	None
Recommendations	Basic knowledge in sanitary engineering
Conditions	None
Learning Outcomes	Students analyze and evaluate basic methods of urban water management. They recognize the interactions between natural and technical systems. They acquire knowledge necessary to identify process engineering solutions and to implement them into functional systems (infrastructure elements). Students are able to describe urban water management issues in the context of watersheds and to take appropriate and environmentally-sound decisions in terms of energy efficiency and costs.

Courses	Title	Type	HPW	Semester		Lecturer
	Urban Water Infrastructure and Management	L/T	4		S	S. Fuchs
Content	This module provides a deep understanding of basic principles needed for the design, analysis and evaluation of urban water systems. The concept of system analysis is introduced to develop models that consider the most important biological, chemical and physical processes and are used to solve water management problems. Based on a detailed consideration of individual elements (subsystems), an overall picture of the water management system Urban Settlement and its interaction with surface and groundwater bodies can be gained. For this purpose, theoretical tools are developed and modeling approaches are reviewed. Students consider the factors energy and costs in the analysis and assessment of water management systems.					
Workload	Attendance time: 60 h Preparation/follow-up: 30 h Lab / project report: 30 h Examination + exam preparation: 60 h					
Literature/ Learning Materials	Metcalf and Eddy (2003) Wastewater Engineering – Treatment and Reuse, McGraw-Hill, New York Imhoff, K. u. K.R. (1999) Taschenbuch der Stadtentwässerung, 29. Aufl., Oldenbourg Verlag, München, Wien					

Advanced Fluid Mechanics

Module Code	AF401
Responsible Lecturer	**Prof. Dr. Olivier Eiff**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the subject 'Advanced Fundamentals' MSc *Civil Engineering*
Instruction Language	English
Duration	1 semester
Module Frequency	Each summer semester
Learning Controls/Exams	Written exam, 90 min
Special Features of the Exam	None
Grade	Grade of the written exam
Requirements	None
Recommendations	A first course in undergraduate fluid-mechanics, advanced engineering mathematics (analysis, differential and integral calculus, ordinary and partial differential equations, linear algebra, Fourier analysis, complex numbers)
Conditions	None
Learning Outcomes	Students acquire a firm understanding of the fundamental mechanics of fluids with emphasis towards environmental flows on the basis of the local conservation laws. They are able to differentiate and apply the different set of assumptions and methods in order to better understand the different flow classes and solutions. They are capable of solving basic flow problems after forming the relevant assumptions. Participants are able to use the knowledge and competence gained for more detailed and applied studies of environmental flows.

Courses	Title	Type	HPW	Semester		Lecturer
	Advanced Fluid Mechanics	L/T	4		S	O. Eiff
Content	This module covers the fundamental mechanics of fluids forming the foundation of environmental fluid mechanics. The approach is based on the basic local conservation laws. Emphasis is on the phenomena and the possible analytical solutions associated with the various flow classes. Topics covered include the general and special forms of the governing equations, flow kinematics, viscous incompressible flows, ideal-fluid flows, shallow flows, and buoyancy effects in fluids. Waves and turbulence are also addressed as well as different methods of analysis such as scaling.					
Workload	Attendance time: 60 h Preparation/follow-up: 30 h Exercises: 30 h Examination + exam preparation: 60 h					
Literature/ Learning Materials	I.G. Currie, Fundamental Mechanics of Fluids, Fourth Edition 2012.					

Numerical Fluid Mechanics

Module Code	AF501
Responsible Lecturer	**Prof. Dr. Markus Uhlmann**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the subject 'Advanced Fundamentals' MSc *Civil Engineering*
Instruction Language	English
Duration	1 semester
Module Frequency	Each winter semester
Learning Controls/Exams	Written exam, 60 min
Special Features of the Exam	None
Grade	Grade of the written exam
Requirements	None
Recommendations	- Fluid Mechanics (knowledge of the fundamental processes of advection and diffusion, familiarity with the Navier-Stokes equations) - Mathematics (analysis -- partial differential equations, Fourier analysis, series expansions, complex numbers; linear algebra - matrices, determinants, eigensystems; numerics - discrete number representation, round-off, floating point operations, numerical treatment of partial differential equations) - Knowledge in programming with Matlab is recommended; otherwise it is strongly recommended to participate in the course 'Introduction to Matlab (CC772)'.
Conditions	None
Learning Outcomes	Students are enabled to describe the fundamental approaches of numerical solution of flow problems. They are capable of evaluating the advantages and disadvantages of these approaches in the various areas of application, enabling them to make an appropriate choice. Participants are able to apply the numerical methods to simple flow problems; this involves the generation and application of basic computer programs. They are able to analyze the results with respect to precision, stability and efficiency.

Courses	Title	Type	HPW	Semester		Lecturer
	Numerical Fluid Mechanics I	L/T	2/2	W		M. Uhlmann
Content	This module constitutes a general introduction to the numerical solution of flow-related problems. The mathematical properties of the conservation equations are analyzed. The principles of numerical discretization are studied with the aid of the finite-difference and the finite-volume method. The concept of numerical stability is introduced, and various techniques of error analysis are presented theoretically and by way of examples.					
Workload	Attendance time: 60 h Preparation/follow-up: 60 h Examination + exam preparation: 60 h					
Literature/ Learning Materials						

Hydraulic Engineering

Module Code	AF601
Responsible Lecturer	**Prof. Dr.-Ing. Franz Nestmann**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the subject 'Advanced Fundamentals' MSc *Civil Engineering*
Instruction Language	English
Duration	1 semester
Module Frequency	Each summer semester
Learning Controls/Exams	Written exam, 75 min
Special Features of the Exam	None
Grade	Grade of the written exam
Requirements	None
Recommendations	None
Conditions	None
Learning Outcomes	Students are able to describe and analyze inter-active water management processes (water-air and water-solid). They are able to assign these basic inter-active processes to engineering tasks and carry out the dimensioning of hydraulic structures with suitable approaches. Based on the acquired process knowledge, they are able to analyze the different results of these dimensioning in a critical manner. Students are able to use and link their knowledge logically. They can work in a reflexive and self-critical manner.

Courses	Title	Type	HPW	Semester		Lecturer
	Multiphase Flow in Hydraulic Engineering	L/T	1/1		S	F. Nestmann
	Design of Hydraulic Structures	L/T	1/1		S	F. Nestmann
Content	The module provides students with basic theoretical and practical aspects of water-air and water-solid interactions as well as the relevance to engineering. The course **Multiphase Flow in Hydraulic Engineering** covers the following topics: - Basic morphodynamics: classification of solids, bed load and suspended load processes - Flow-sediment interaction: approaches to bed load transport rates - Suspended load transport: diffusion theory by Schmidt - Mass transport at waterbeds: structures, development, modeling - Hydromorphological processes: theory by Ahnert, space-time models, sediment transport models - Water-air mixes: basics, behavior specification, engineering applications In the course **Design of Hydraulics Structures**, the following topics are discussed in depth: - Overview: hydraulic structures and water management and their integration in the river system - Design procedures, engineer standards and state of the art in hydraulic structures					
Workload	Attendance time: 60 h Preparation/follow-up: 60 h Examination + exam preparation: 60 h					
Literature/ Learning Materials						

Water and Energy Cycles

Module Code	AF701
Responsible Lecturer	**Prof. Dr.-Ing. Erwin Zehe**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the subject 'Advanced Fundamentals' MSc *Civil Engineering* MSc *Geoecology*
Instruction Language	English
Duration	1 semester
Module Frequency	Each winter semester
Learning Controls/Exams	Oral exam, 30 min
Special Features of the Exam	None
Grade	Grade of the oral exam
Requirements	None
Recommendations	Knowledge of programming with Matlab. Otherwise, it is strongly recommended to participate in the course 'Introduction to Matlab (CC772)'. Knowledge of hydrology and engineering hydrology
Conditions	None
Learning Outcomes	Students are able to explain the most relevant processes of the terrestrial water and energy cycles including their feedbacks and limitations. They know the concepts to quantitatively describe and predict these processes in the context of science and water management and are able to independently apply related computer-based tools for analysis and prediction for standard situations. Students are able to evaluate the required data and to quantify and evaluate the uncertainties related to the simulations and predictions.

Courses	Title	Teaching mode	Hours/ week	Semester		Lecturer
	Water and Energy Cycles in Hydrological Systems: Processes, Predictions and Management	L/T	4	W		E. Zehe, U. Ehret, J. Wienhöfer
Content	This module deepens the fundamentals of the water and energy cycles with particular regard to: - the soil as the central control element of the water and energy cycle and he interplay of soil water and ground heat balance - evaporation, energy balance and processes in the atmospheric boundary layer - runoff and evaporation regimes in different hydro-climates; - water balance and floods at the catchment scale and statistics for water management - the interplay between runoff processes and soil water balance, and the soil as filter system - concepts of hydrological similarity and comparative hydrology - process-based and conceptual models to predict floods, the water balance and evaporation					
Workload	Attendance time: 60 h Preparation/follow-up: 60 h Examination + exam preparation: 60 h					
Literature/ Learning Materials	Kraus, H. (2000): Die Atmosphäre der Erde. Vieweg S. P. Aryan (2001): Introduction to Micrometeorology, 2nd Ed., Academic Press Hornberger et al. (1998): Elements of physical hydrology. John Hopkins University Press Beven, K. (2004): Rainfall runoff modelling – The primer: John Wiley and Sons Plate, E. J.,Zehe, E. (2008): Hydrologie und Stoffdynamik kleiner Einzugsgebiete. Prozesse und Modelle, Schweizerbart, Stuttgart, 2008.					

Hydrogeology

Module Code	AF801
Responsible Lecturer	**Prof. Dr. Nico Goldscheider**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the subject 'Advanced Fundamentals'
Instruction Language	English
Duration	2 semesters, starting in winter semester
Module Frequency	Each winter semester
Learning Controls/Exams	Written exam, 90 min
Special Features of the Exam	None
Grade	Grade of the written exam
Requirements	None
Recommendations	None
Conditions	None
Learning Outcomes	Students are familiar with the advanced fundamentals and methods of hydrogeology. They are able to describe the processes of water transport in the subsurface quantitatively, and they can explain the hydrochemical interactions of water and rocks. Students are capable of solving practical hydrogeological problems related to the exploration, exploitation and protection of groundwater.

Courses	Title	Type	HPW	Semester		Lecturer
	General and Applied Hydrogeology	L/T	1/1	W		N. Goldscheider
	Field Methods in Hydrogeology	L/T	1		S	T. Liesch, N. Göppert
Content	**General and Applied Hydrogeology:** - Subterraneous discharge: process characteristics, measurement techniques and calculation methods, regional and temporal variations - Water transport in the subsurface, groundwater hydraulics - Hydrochemistry - Groundwater use: exploration of groundwater resources, exploitation of groundwater, and groundwater protection - Regional hydrogeology **Field Methods in Hydrogeology:** - Pumping tests and other hydraulic tests - Tracer tests - Hydrochemical sampling and monitoring					
Workload	Attendance time: 45 h Preparation/follow-up: 65 h Examination + exam preparation: 70 h					
Literature/ Learning Materials	Fetter, C.W. (2001) Applied Hydrogeology. Prentice Hall: 598 S. Hölting, B. & Coldewey, W.G. (2009) Einführung in die Allgemeine und Angewandte Hydrogeologie, Spektrum Akademischer Verlag: 384 S. Keller, E.A. (2000) Environmental Geology. Prentice Hall: 562 S. Langguth, H.R. & Voigt, R. (2004) Hydrogeologische Methoden, 2. Aufl., Springer: 1005 S. Mattheß, G. (1994) Die Beschaffenheit des Grundwassers, 3. Aufl., Borntraeger: 499 S. Mattheß, G. & Ubell, K. (2003) Allgemeine Hydrogeologie – Grundwasserhaushalt, 2. Aufl., Borntraeger: 575 S. Younger, P. (2007) Groundwater in the Environment: An Introduction. Blackwell Publishing: 318 S.					

2.3 Cross-Cutting Methods & Competencies

Experiments in Fluid Mechanics

Module Code	CC471
Responsible Lecturer	**Prof. Dr. Olivier Eiff**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the subject 'Cross Cutting Methods and Competencies' MSc *Civil Engineering*
Instruction Language	German/English
Duration	1 semester
Module Frequency	Each summer semester
Learning Controls/Exams	Oral exam, 30 min Prerequisite for the exam: preparation of reports on the laboratory experiments in small student teams (approx. 10 pages including figures and tables)
Special Features of the Exam	None
Grade	Grade of the oral exam
Requirements	None
Recommendations	Fundamentals of fluid mechanics
Conditions	None
Learning Outcomes	Students relate the hydrodynamics theory and physical concepts to the observed physical reality. They apply their knowledge and skills for the comparative analysis of basic flow situations in physical models, using appropriate measurement technologies. They assess and evaluate the results and limitations by comparing their results with theoretical deductions. They extend their results of phenomena-oriented experiments with regard to practical applications in technical hydraulics and environmental flows. Acquired competence: operation of test facilities and instrumentation, data analysis and basic statistical error analysis, team work, written and oral communication.

Courses	Title	Type	HPW	Semester		Lecturer
	Experimental Methods and Physical Experiments/ Experimentelle Methoden und physikalische Experimente	L/T	1/3		S	O. Eiff, C. Lang
Content	**Lecture:** - Typical set-up of hydraulic and aerodynamic models - Dimensional analysis, dimensionless parameters - Measurement instrumentation - Introduction to statistical error analysis - Analogy numerical/physical modeling, model distortion - Technical writing and oral presentation **Physical experiments:** - Pipe flow with orifice plate - Open channel flow with gates and hydraulic jumps - Venturi pipe flow with cavitation - Settling velocities of spheres - Diffusion of a turbulent air jet - Turbulent wake - Dam leakage					
Workload	Attendance time: 60 h Preparation/follow-up: 30 h Evaluation and reporting experimental results: 60 h Examination + exam preparation: 30 h					
Literature/ Learning Materials						

Data Analysis and Environmental Monitoring

Module Code	CC771
Responsible Lecturer	**Prof. Dr.-Ing. Erwin Zehe**
Level	4
ECTS Credits	9
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the subject 'Cross Cutting Methods and Competencies' MSc *Geoecology*
Instruction Language	Geostatistics: English Analysis of Hydrological Time Series: German
Duration	2 semesters
Module Frequency	Each semester
Learning Controls/Exams	Oral exam, 30 min
Special Features of the Exam	None
Grade	Grade of the oral exam
Requirements	None
Recommendations	Statistics Module Experimental Hydrology Knowledge in programming with Matlab. Otherwise, it is strongly recommended to participate in the module 'Introduction to Matlab'.
Conditions	None
Learning Outcomes	Students can explain and apply methods for analysis and simulation of spatially and temporally distributed environmental data. Based on this, they are capable of setting up experimental designs for environmental monitoring and evaluate the suitability of available data for different tasks. Students are able to critically assess the results of analysis and simulation tools and to quantify and evaluate the related uncertainties.

Courses	Title	Type	HPW	Semester		Lecturer
	Geostatistics	L/T	2/2		S	E. Zehe
	Analysis of Hydrological Time Series/ Analyse hydrologischer Zeitreihen	L/T	1/1	W		J. Ihringer

Content

Geostatistics:

- Fundamentals of environmental systems theory, environmental monitoring and experimental design (data types, scale triplet, measuring methods)
- Experimental variograms, directional variograms, indicator variograms, variogram fitting, anisotropy
- Kriging techniques: Ordinary Kriging, screening properties of Kriging, BLUE, pure nugget effect, cross validation, RMSE
- Estimation of spatial patterns in nonstationary data (External Drift Kriging, Simple Updating)
- Simulation of spatial patterns: Turning Bands Simulation, smoothing problems of interpolation

Analysis of Hydrological Time Series:

- Fundamentals of time series analysis
- Tests for homogeneity, stationarity and outliers
- Extreme-value statistics of high and low flows for design purposes
- Time series components: trend, periodicity, residuals
- Concepts to describe residuals
- Time series generation: fundamentals, generation of artificial annual-, monthly and daily values
- Stochastic reservoir design
- Application examples using statistical computer software

Workload

Attendance time: 90 h

Preparation/follow-up: 120 h

Examination + exam preparation: 60 h

Literature/ Learning Materials

Bárdossy, A. (2001): Introduction into Geostatistics. Inst. f. Wasserbau, Universität Stuttgart.

Kitanidis, P. K. (1999): Introduction into Geostatistics. Applications in Hydrogeology. Cambridge University Press.

Bras, R. L. and Rodriguez-Iturbe, I. (1985): Random Functions and Hydrology. Addison-Wesley Massachusetts.

Brooker, I. (1982): Two-dimensional simulation by turning bands. Math. Geology 17 (1).

Water Ecology

Module Code	CC371
Responsible Lecturer	**Dr.-Ing. Stephan Fuchs/Dr. Stephan Hilgert**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the subject 'Cross Cutting Methods and Competencies' MSc *Civil Engineering*
Instruction Language	English
Duration	1 semester
Module Frequency	Each summer semester
Learning Controls/Exams	Examination of other type, consisting of a written assignment (8-15 pages) and a presentation (15 min.) Ungraded learning control "Field Training Water Quality": Report (8-15 pages)
Special Features of the Exam	None
Grade	Grade of the examination of other type
Requirements	None
Recommendations	None
Conditions	None
Learning Outcomes	Students get familiar with the basic principles of water ecology in surface waters. They are able to explain interactions between abiotic control factors (flow, chemistry, structure) and their relevance for the ecological status of standing waters and streams and to evaluate them critically. They become acquainted with field and laboratory techniques to establish water quality. With the help of these methods, they evaluate data-quality of information collected in the field regarding chemical, biological and structural water quality and determine the level of uncertainty intrinsic to the data-collection methods. Using case studies, students are able to convey and evaluate positive results as well as restrictions from water restoration processes.

Courses	Title	Type	HPW	Semester		Lecturer
	Applied Ecology and Water Quality	L/S	3		S	S. Fuchs, S. Hilgert
	Field Training Water Quality	T	1		S	S. Fuchs, S. Hilgert
Content	As part of the module, water ecology principles, their practical significance and implementation of restoring measures are presented. The following topics are covered: - Pollutants loads discharged into water bodies: discharge points, pollutants, sediment problems - Sampling methods - Oxygen content - Methods for the assessment of water quality and water general status - Practical exercises to measure water quality and condition in the field Students get acquainted with practical examples of water protection and water remediation measures and they interpret and discuss them as part of an individual assignment. For this purpose, they implement their own framework, based on visible requirements and achievable targets.					
Workload	Attendance time: Applied Ecology and Water Quality (L/S): 45 h Field Training Water Quality (block course): 20 h Report field training (uLC): 55 h Examination + exam preparation (assignment and presentation): 60 h					
Literature/ Learning Materials	Wetzel, Limnology, 3rd Edition, Academic Press 2001 Schwörbel, Methoden der Hydrobiologie, UTB für Wissenschaft 1999 Lecture Notes					

Instrumental Analysis

Module Code	CC921
Responsible Lecturer	**PD Dr. Gisela Guthausen/Dr. Gerald Brenner-Weiß**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the subject 'Cross Cutting Methods and Competencies'
Instruction Language	English (optionally in German)
Duration	1 semester
Module Frequency	Each summer semester
Learning Controls/Exams	Oral exam, 30 min Ungraded learning control as a prerequisite for the exam: written report on the laboratory data (maximum 5 pages)
Special Features of the Exam	Ungraded learning control as prerequisite
Grade	Grade of the oral exam
Requirements	None
Recommendations	Module 'Fundamentals of Water Quality (AF201)'
Conditions	None
Learning Outcomes	Students are familiar with the important methods of modern instrumental analysis and their range of application. They can explain the basic physical principles of the methods. Students are able to develop solutions for analytical problems, to choose adequate procedures for sample preparation and measuring techniques. They can evaluate the measurement data and interpret the results.

Courses	Title	Type	HPW	Semester		Lecturer
	Instrumental Analysis	V	2		S	G. Guthausen
	Organic Trace Analysis of Aqueous Samples	P	2		S	G. Brenner-Weiß
Content	**Instrumental Analysis:** Introduction to selected methods of modern instrumental analysis: - Optical methods - Magnetic resonance methods, mass spectrometry - Imgaging methods as MRT, µCT and optical methods (CLSM and OCT) - Basics of data analysis and image processing **Organic Trace Analysis of Aqueous Samples:** Laboratory course on methods for sample concentration, sample preparation, and analysis of organic trace compounds in aqueous samples using HPLC coupled with tandem mass spectrometry (LC-MSMS) To participate in the lab course, please make an appointment with Dr. Brenner-Weiß (IFG).					
Workload	Attendance time: 60 h Preparation/follow-up: 60 h Report on laboratory course: 30 h Examination + exam preparation: 30 h					
Literature/ Learning Materials	Lecture notes					

Microbial Diversity/Mikrobielle Diversität

Module Code	CC922
Responsible Lecturer	**Prof. Dr. Johannes Gescher**
Level	4
ECTS Credits	9
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the subject 'Cross Cutting Methods and Competencies' MSc *Biology*
Instruction Language	German
Duration	1 semester, third period of winter semester (4 weeks)
Module Frequency	Each winter semester
Learning Controls/Exams	- See German version
Special Features of the Exam	- See German version
Grade	- See German version
Requirements	None
Recommendations	Module 'Applied Microbiology (PA982)'
Conditions	None
Restrictions	The places in this module are limited. Please contact the study advisor for biology (*Studienberatung Biologie*) in time, at latest during September.
Learning Outcomes	- See German version

Courses	Title	Type	HPW	Semester		Lecturer
	Microbial Diversity/ Mikrobielle Diversität	L	2	W		J. Gescher
	Laboratory Course: Microbial Diversity/ Praktikum: Mikrobielle Diversität	P	6	W		J. Gescher
Content	- See German version					
Workload	Attendance time lecture: 15 h Attendance time lab course: 90 h Preparation/follow-up lecture: 20 h Preparation/follow-up lab course: 145 h					
Literature/ Learning Materials	- See German version					

Principles of Sustainable Water Management

Module Code	CC907
Responsible Lecturer	**Dr. Helmut Lehn**
Level	4
ECTS Credits	3
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the subject 'Cross Cutting Methods and Competencies'
Instruction Language	English
Duration	1 semester
Module Frequency	Each winter semester
Learning Controls/Exams	Examination of other type, consisting of a presentation (20 min.) and a written report (10 - 15 pages)
Special Features of the Exam	None
Grade	Grade of the examination of other type
Requirements	None
Recommendations	None
Conditions	None
Restrictions	Minimum number of participants: 8
Learning Outcomes	Students understand the basic idea of the sustainability principle. They are able to apply it to different aspects of water use using appropriate concepts. They are thus capable of analyzing and evaluating the sustainability of various water technologies in a specific context (biogeographic, economic and social), and they can present and justify their assessments.

Courses	Title	Type	HPW	Semester		Lecturer
	Principles of Sustainable Water Management	S	2	W		H. Lehn
Content	This module provides an introduction to the principles of sustainability and of sustainable development, including an overview on the historical development of these principles and its current implementations. Various aspects of water use, water management and related technologies are analyzed and assessed in terms of the particular sustainability performance, based on the guidelines of the integrative sustainability concept of the Helmholtz Association.					
Workload	Attendance time: 30 h Preparation/follow-up: 20 h Presentation and report: 40 h					
Literature/ Learning Materials	Lehn H, Steiner M, Mohr H (1996): Wasser, die elementare Ressource – Leitlinien einer nachhaltigen Nutzung. Berlin, Heidelberg, New York: Springer Grunwald A, Kopfmüller J (2012): Nachhaltigkeit: 2., aktualisierte Auflage. Frankfurt: Campus					

Infrastructure Planning – Socio-economic & Ecological Aspects

Modul Code	CC791
Responsible Lecturer	**Dr. Charlotte Kämpf**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the subject 'Cross Cutting Methods and Competencies'
Instruction Language	English
Duration	1 Semester
Module Frequency	Each winter semester
Learning Controls/Exams	Written exam with focus on socio-economic aspects, 60 min Ungraded learning control as prerequisite for the exam: Booklet DIN A5, about 15 pages, with focus on ecology und environmental impact assessment
Special Features of the Exam	None
Grade	Grade of the written exam
Requirements	None
Recommendations	None
Conditions	None
Learning Outcomes	Students are able to rank interdisciplinary texts on development planning according to their relevance, and formulate relevant questions on this topic. Students can research systematically on a scientific problem, and they can use different technical terms. They are able to put the materials in the context of integrated development planning and current water resources problems to work on solutions for adapting to regional conditions.

Courses	Title	Type	HPW	Semester		Lecturer
	Infrastructure Planning – Socio-economic & Ecological Aspects	L/S/T	4	W		Ch. Kämpf R. Walz
Content	**Socio-economic aspects:** - Natural resources as economic goods - Scenario analysis of depletion and capacity of natural resources, assessment of values, additional costs - Coordination of activities on economic development; strategical planning, indicator systems - Cost-benefit analyses, investment criteria **Ecological aspects / environmental impact assessment:** - Biodiversity, habitats, resilience, structure and dynamics of ecosystems; nutrient cycling - Bioindicators, ecosystem services - History of environmental impact assessment (EIA), EIA in the EU, in other countries - Impact assessment in the EW-project management (mitigation, compensation, monitoring, auditing)					
Workload	Attendance time: 40 h (lecture and seminar) Preparation/follow-up: 20 h Exam prerequisite (booklet): 60 h Exam and exam preparation:60 h					
Literature/ Learning Materials						

Environmental Communication/ Umweltkommunikation

Modul Code	CC792
Responsible Lecturer	**Dr. Charlotte Kämpf**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the subject 'Cross Cutting Methods and Competencies' MSc *Industrial Engineering* MSc *Geodesy* MSc *Civil Engineering*
Instruction Language	German (material partly in English)
Duration	1 Semester
Module Frequency	Each winter semester
Learning Controls/Exams	- See German version
Special Features of the Exam	None
Grade	- See German version
Requirements	None
Recommendations	None
Conditions	None
Learning Outcomes	- See German version

Courses	Title	Type	HPW	Semester		Lecturer
	Umweltkommunikation/Environmental Communication	S	2	W		Ch. Kämpf
Content	- See German version					
Workload	- See German version					
Literature/ Learning Materials						

Introduction to Matlab

Module Code	CC772
Responsible Lecturer	**Dr.-Ing. Uwe Ehret**
Level	4
ECTS Credits	3
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the subject 'Cross Cutting Methods and Competencies' MSc *Civil Engineering* MSc *Geoecology*
Instruction Language	English
Duration	1 semester
Module Frequency	Each winter semester
Learning Controls/Exams	Ungraded learning control, composed of ungraded assignments and a take-home exam (writing a Matlab program and a report of about one page)
Special Features of the Exam	None
Grade	The module is not graded (pass/fail).
Requirements	None
Recommendations	None
Conditions	None
Restrictions	The course is limited to 60 participants. Please register via the student portal (Studierendenportal). Only in case that this should not be possible: Please register via e-mail to the responsible lecturer. Participants are selected according to their year of study and in the following order: Students of *Water Science and Engineering*, then students of *Civil Engineering* with focus "Water and Environment", then other students of the module „Thermodynamics of Environmental Systems (PC741)"
Learning Outcomes	Students are familiar with common programming rules and the working environment and basic syntax of Matlab. They are capable of independently formulating and coding simple programs for data analysis and visualization as well as simulation of dynamical systems with Matlab. Students have thus gained the competence to independently solve computer-based modeling tasks in advanced courses. Students are able to solve problems and to present the related results in teamwork.

Courses	Title	Type	HPW	Semester		Lecturer
	Introduction to Matlab	L/T	1/1	W		U. Ehret, J. Wienhöfer
Content	- Universal programming basics: Programing strategies, program structures, control structures, operators and variables, functions and objects, matrix calculations - Basics of Matlab: History, installation, graphical user interface, tool boxes, using help - Matlab programming basics: syntax, debugging, reading and writing of files, data visualization Take-home programming assignments - Programs to analyze and visualize observation data - Design and implementation of a simple dynamical model - Preparation of ungraded assignments and presentation in small groups					
Workload	Attendance time: 30 h Preparation/follow-up: 10 h Homework: 30 h Take-home exam: 20 h					
Literature/ Learning Materials						

Probability and Statistics

Module Code	CC911
Responsible Lecturer	**Dr. Bernhard Klar**
Level	4
ECTS Credits	3
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the subject 'Cross Cutting Methods and Competencies'
Instruction Language	English
Duration	1 semester
Module Frequency	Each summer semester
Learning Controls/Exams	Oral exam (about 20 min)
Special Features of the Exam	None
Grade	Grade of the oral exam
Requirements	None
Recommendations	None
Conditions	None
Learning Outcomes	- Students acquire basic knowledge of probability theory, and are able to model simple random phenomena. - They know the basic differences between descriptive and inferential statistics. - Students learn basic statistical methods, and are able to apply this knowledge to new examples.

Courses	Title	Type	HPW	Semester		Lecturer
	Probability and Statistics	L	2		S	B. Klar
Content	The lecture gives a concise introduction to probability theory and covers some important statistical methods. Key terms: random experiments, events, probability, conditional probability, independent events, random variables, probability distribution, density, sample mean, sample variance, sample correlation, point estimate, confidence interval, test, error propagation, linear regression.					
Workload	Attendance time: 30 h Preparation/follow-up: 35 h Examination + exam preparation: 25 h					
Literature/ Learning Materials	Kottegoda, N.T. and R. Rosso (2008). Applied Statistics for Civil and Environmental Engineers. Wiley-Blackwell, 736 pp. (strongly suggested) Devore, J.L. (2011) Probability and Statistics for Engineering and the Sciences. Duxbury Press. Lefebvre, M. (2006). Applied Probability and Statistics. Springer. Ross, S.M. (2009). Introduction to Probability and Statistics for Engineers and Scientists. Academic Press.					

Remote Sensing and Positioning

Module Code	CC931
Responsible Lecturer	**Dr.-Ing. Thomas Vögtle/Dr.-Ing. Michael Mayer**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the subject 'Cross Cutting Methods and Competencies'
Instruction Language	English
Duration	1 semester
Module Frequency	Each winter semester
Learning Controls/Exams	Oral exam, 30 min
Special Features of the Exam	None
Grade	Grade of the oral exam
Requirements	None, yet see recommendations below
Recommendations	Fundamentals of geometric optics, oscillations and waves, linear algebra (vectors, coordinate geometry, trigonometry)
Conditions	None
Learning Outcomes	The module enables students to understand and to apply surveying and remote sensing methods. It provides tools for data processing and uncertainties as well as for spatial data management and visualization. Students gain insight into processing resp. generating and analysis chains of remote sensing and geo-informatics; covering data acquisition techniques, data filtering, statistical assessment, 3D modeling, model assimilation/adaption, and critical evaluation.

Courses

Title	Type	HPW	Semester		Lecturer
Terrestrial & Satellite Positioning	L/T	1/1	W		M. Mayer, M. Hennes
Remote Sensing & Geo-Information Systems	L/T	1/1	W		Th. Vögtle, S. Hinz

Content

Terrestrial & Satellite Positioning:

- Definition of reference systems and realization of reference frames
- Satellite positioning: GNSS segments, code and phase measurements, error sources, differential and absolute positioning, RTK and static mode
- 3D point/position, height calculation
- Terrestrial surveying of heights: methods and introduction to

	instruments - Satellite positioning: GNSS description, signals, error sources and error reduction, processing strategies, absolute and differential GNSS, real-time, post-processing, planning a GNSS project, services - Comparison of terrestrial and satellite-based height determination **Remote Sensing & Geo-Information Systems:** - Electromagnetic spectrum; sensors and data of remote sening, image processing; strategy of development of GIS, definition and example, standardization; reference and coordinate systems, deformation and rectification, digital terrain models - Data processing: histograms, multispectral classification, quality assessment - Examples of Remote Sensing Applications - Sensors and systems: Airborne vs. satellite platforms, metric cameras, scanner, radar Exercise: Introduction to Remote Sensing Software, Multi-spectral classification, evaluation techniques
Workload	Attendance time: 60 h Preparation/follow-up: 60 h Examination + exam preparation: 60 h
Literature/ Learning Materials	Bannister, A., S. Raymond, R. Baker (1998). Surveying. Longman. Elfick, M., J. Fryer, B. Brinker and P. Wolf (1995). Elementary surveying. Harper Collins. Hofmann-Wellenhof, B., H. Lichtenegger, J. Collins (2001). Global Positioning System, 5/e. Theory and Practice. Springer. Hofmann-Wellenhof, B., H. Lichtenegger, E. Wasle (2007). GNSS - Global Navigation Satellite Systems: GPS, GLONASS, Galileo & more. Springer. Hoffmann-Wellenhof, B., H. Moritz (2005). Physical Geodesy. Wien: Springer. Kraus, K. (2007). Photogrammetry (Vol. I): Geometry from Images and Laser Scans, 2/e. Berlin, D: de Gruyter. Lillesand, T. and R. Kiefer (2000). Remote Sensing and Image Interpretation, 4/e. John Wiley. Richards, J. A., X. Jia (2006). Remote sensing digital image analysis: an introduction, 4/e. Birkhäuser. Seeber, G. (2003). Satellite Geodesy – Foundations, Methods and Applications. 2nd ed., Berlin: De Gruyter. Torge, W. (2001). Geodesy, 3/e. Berlin, D: de Gruyter. Lecture notes: Heck, B.; Mayer, M., K. Seitz. “Terrestrial & Satellite Positioning”

Introduction to GIS for Students of Natural, Engineering and Geo Sciences/ Einführung in GIS für Studierende natur-, ingenieur- und geowissenschaftlicher Fachrichtungen

Module Code	CC933
Responsible Lecturer	**Dr.-Ing. Norbert Rösch/Dr.-Ing. Sven Wursthorn**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the subject 'Cross Cutting Methods and Competencies'
Instruction Language	German
Duration	1 semester
Module Frequency	Each winter semester
Learning Controls/Exams	Written exam, 90 min. Exam prerequisite: passing an online test
Special Features of the Exam	None
Grade	Grade of the written exam
Requirements	None
Recommendations	None
Conditions	None
Learning Outcomes	- See German version

Courses	Title	Type	HPW	Semester		Lecturer
	Introduction to GIS for Students of Natural, Engineering and Geo Sciences/ Einführung in GIS für Studierende natur-, ingenieur- und geowissenschaftlicher Fachrichtungen	L/T	2/2	W		N. Rösch, S. Wursthorn
Content	- See German version					
Workload	Attendance time: 60 h Preparation/follow-up: 60 h Examination + exam preparation: 60 h					
Literature/ Learning Materials	Bill, Grundlagen der Informationssysteme, Wichmann, 2010 Online resources Lecture notes					

Spatial Data Infrastructures and Web Services/ Geodateninfrastrukturen und Webdienste

Module Code	CC935
Responsible Lecturer	**Dr.-Ing. Sven Wursthorn**
Level	4
ECTS Credits	4
Study Program	MSc Water *Science & Engineering*, compulsory elective module in the subject 'Cross Cutting Methods and Competencies'
Instruction Language	German
Duration	1 semester, block course in the second half of the summer semester
Module Frequency	Each summer semester
Learning Controls/Exams	Oral exam, 20 min. Exam prerequisite: completion of exercises
Special Features of the Exam	None
Grade	Grade of the oral exam
Requirements	None
Recommendations	None
Conditions	None
Learning Outcomes	- See German version

Courses	Title	Type	HPW	Semester		Lecturer
	Spatial Data Infrastructures and Web Services/ Geodateninfrastrukturen und Webdienste	L/T	1/2		S	S. Wursthorn
Content	- See German version					
Workload	Attendance time: 15 h Preparation/follow-up: 80 h Examination + exam preparation: 20 h					
Literature/ Learning Materials	Lecture notes Bill, Grundlagen der Informationssysteme, Wichmann, 2010 Online resources					

Numerical Mathematics for Informatics and Engineering/ Numerische Mathematik für die Fachrichtungen Informatik und Ingenieurwesen

Module Code	CC912
Responsible Lecturer	**Dr. Daniel Weiß** **Prof. Dr. Christian Wieners** **Prof. Dr. Andreas Rieder**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the subject 'Cross Cutting Methods and Competencies' MSc *Mechanical Engineering*
Instruction Language	German
Duration	1 semester
Module Frequency	Each summer semester
Learning Controls/Exams	Written exam, 120 min
Special Features of the Exam	None
Grade	Grade of the written exam
Requirements	None
Recommendations	Higher Mathematics/Calculus
Conditions	None
Learning Outcomes	- See German version

Courses	Title	Type	HPW	Semester		Lecturer
	Numerical Mathematics for Informatics and Engineering/ Numerische Mathematik für die Fachrichtungen Informatik und Ingenieurwesen	L/T	2/1		S	D. Weiß
Content	- See German version					
Workload	Attendance time: 45 h Preparation/follow-up: 65 h Examination + exam preparation: 70 h					
Literature/ Learning Materials	- See German version					

Language Skills

Module Code	CC949
Responsible Lecturer	**Sprachenzentrum/ Studienkolleg für ausländische Studierende**
Level	4
ECTS Credits	2 - 6 (depending on the selected language course)
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the subject 'Cross Cutting Methods and Competencies'
Instruction Language	-
Duration	1 or 2 semesters (depending on the selected language course)
Module Frequency	Each semester
Learning Controls/Exams	Written exam
Special Features of the Exam	Attendance of classes is compulsory. Further information is provided by *Sprachenzentrum* (www.spz.kit.edu), *Studienkolleg für ausländische Studierende* (www.stk.kit.edu).
Grade	The module is not graded (pass/fail).
Requirements	None
Recommendations	None
Conditions	Language courses in the native language of the student are not accredited. English language courses below the level required for admission to the master's degree program *Water Science & Engineering* are not accredited.
Learning Outcomes	Students acquire skills in cross-cultural communication.
Content	Students can acquire and improve knowledge of a language of their choice. Information on the courses offered and on the registration procedure are given at www.spz.kit.edu. Students who are not native German speakers may attend German courses at *Studienkolleg*: www.stk.kit.edu/deutsch_kurse.php.
Workload	Attendance time: 30 - 90 h Preparation/follow-up: 30 - 90 h (depending on the selected language course) The courses of *Sprachenzentrum* and *Studienkolleg* are accredited with one CP per class hour per week.

2.4 Profile A: Water Technologies & Urban Water Cycle

Water Technology

Module Code	PA221
Responsible Lecturer	**Prof. Dr. Harald Horn**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Water Technologies and Urban Water Cycle' MSc *Chemical Engineering*
Instruction Language	English
Duration	1 semester
Module Frequency	Each winter semester
Learning Controls/Exams	Oral exam, 30 min
Special Features of the Exam	None
Grade	Grade of the oral exam
Requirements	None
Recommendations	None
Conditions	None
Learning Outcomes	Students learn fundamental knowledge in water chemistry and how to apply it to processes in aquatic systems in general and in reactors for water treatment. Water treatment will be taught for drinking water and partly waste water. The students are able to apply physical, chemical and biochemical treatment for the respective removal of particulate and dissolved components in water. They are able to use the fundamental design parameters for the different types of unit operations.

Courses	Title	Type	HPW	Semester		Lecturer
	Water Technology	L/T	3	W		H. Horn
Content	Water cycle, different types of raw water (ground and surface water). Water as solvent, carbonate balance, differentiation between microbiological and chemical population. Unit operations: sieving, sedimentation, filtration, flocculation, flotation, ion exchange, aeration, oxidation, disinfection, adsorption). For all unit operations design parameters will be provided. Simple 1D models will be discussed for description of kinetics and retention time in reactors for water treatment.					
Workload	Attendance time: 45 h Preparation/follow-up: 60 h Examination + exam preparation: 75 h					
Literature/ Learning Materials	Crittenden et al. (2005): Water Treatment, Principles and design. Wiley & Sons, Hoboken DVGW-Handbuch (2004): Wasseraufbereitung-Grundlagen und Verfahren, Oldenbourg, München. Lecture notes will be provided in ILIAS					

Membrane Technologies and Excursions

Module Code	PA222
Responsible Lecturer	**Prof. Dr. Harald Horn/Dr.-Ing. Florencia Saravia**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Water Technologies and Urban Water Cycle' MSc *Chemical Engineering*
Instruction Language	English
Duration	2 semesters**
Module Frequency	Each semester**
Examinations/Partial Deliveries	Oral exam, 30 min
Special Features of the Exam	None
Grade	Grade of the oral exam
Requirements	None
Recommendations	Module 'Water Technology (PA221)'
Conditions	None
Learning Outcomes	Students have a fundamental knowledge on membrane technology in water and waste water treatment. They learn how the different membrane systems (reverse osmosis, nanofiltration, ultrafiltration, microfiltration, and dialysis) have to be applied to produce a certain water quality. They are able to design such systems.

Courses	Title	Teaching mode	Hours/ week	Semester		Lecturer
	Membrane Technologies in Water Treatment	L	2	W**		H. Horn, F. Saravia
	Waste Water Disposal and Drinking Water Supply – Introduction and Excursions	L/E	1		S	G. Abbt-Braun
Content	The solution-diffusion model. Concentration polarization and the consequences for membrane module design. Membrane production and properties. Membrane configuration and design. Membrane systems for desalination and brackish water treatment. Membrane bio reactors for waste water treatment. Biofouling, scaling and prevention of both. Introduction to excursions and excursions: basic processes in waste water disposal and drinking water supply, including visits to municipal waste water treatment plants and treatment plants for drinking water.					
Workload	Attendance time: 55 h Preparation/follow-up: 60 h Examination + exam preparation: 65 h					
Literature/Learning Materials	Melin, T.; Rautenbach, R.: "Membranverfahren - Grundlagen der Modul- und Anlagenauslegung", Springer Verlag Berlin Heidelberg, 2007 Mulder, Marcel H.: “Basic principles of membrane technology“, Kluwer Academic, Dordrecht, 2000 Schäfer, A. I.: „Nanofiltration: principles and applications“, Elsevier, Oxford, 2005 Staude, E.: "Membranen und Membranprozesse", Verlag Chemie, Weinheim, 1992 Lecture Notes in ILIAS					

** The lecture „Membrane Technologies in Water Treatment“ will be given in 2017/18 for the last time in winter semester. Starting from summer semester 2019, the lecture will be given in summer.

Applied Microbiology

Module Code	PA982
Responsible Lecturer	**Prof. Dr. Thomas Schwartz/Prof. Dr. Andreas Tiehm**
Level	4
ECTS Credits	8
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Water Technologies and Urban Water Cycle'
Instruction Language	English
Duration	2 semesters, starting in summer semester
Module Frequency	Each summer semester
Learning Controls/Exams	Partial exam 'Microbiology for Engineers' (4 CP): Oral exam, 30 min. Partial exam on 'Environmental Biotechnology' (4 CP): Oral exam, 30 min.
Special Features of the Exam	None
Grade	Weighted average of the grades of the partial exams according to credit points
Requirements	None
Recommendations	Understanding of microbiological processes in the environment and in technical systems
Conditions	None
Learning Outcomes	Students can explain the microbiological principles and their technical applications. Students are able to apply technically relevant biochemical and molecular biology issues to ecological, biotechnical and environmental processes. They can analyze and evaluate factors limiting operations in e.g. biotechnology and water technology and can combine processes for enhanced turnover rates in the sense of ecology and/or economy.

Courses	Title	Type	HPW	Semester		Lecturer
	Microbiology for Engineers	L	2		S	T. Schwartz
	Environmental Biotechnology	L	2	W		A. Tiehm
Content	Main issues are the structures and functions of microorganisms, their interactions with global element cycles and other organisms, the microbial impact on energy and corrosion as well as strategies against microbes. Basing on the fundamental metabolism biotechnology operations and specific monitoring strategies are presented.					
Workload	Attendance time: 60 h Preparation/follow-up:90 h Examination + exam preparation: 90 h					
Literature/ Learning Materials						

Practical Course in Water Technology

Module Code	PA223
Responsible Lecturer	**Prof. Dr. Harald Horn**
Level	4
ECTS Credits	4
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Water Technologies and Urban Water Cycle' MSc *Chemical Engineering*
Instruction Language	English
Duration	1 semester
Module Frequency	Each summer semester
Examinations/Partial Deliveries	Examination of other type, consisting of protocols of the experiments, an oral presentation, and an oral exam (15 min)
Special Features of the Exam	The other parts of the exam (protocols and presentation) have to be passed before taking the oral exam
Grade	The overall grade of the examination of other type is taken as the weighted average from the individual parts (protocols 40 %, oral presentation 10 %, oral exam 50 %).
Requirements	Module 'Water Technology (PA221) '
Recommendations	None
Conditions	None
Learning Outcomes	Students can explain the most important processes in water treatment. They are able to do calculations, and to compare and interpret data. They learn how to use different methods, and to interpret different processes.

Courses	Title	Type	HPW	Semester		Lecturer
	Practical Course in Water Technology	V/P	2		S	H. Horn, G. Abbt-Braun, A. Hille-Reichel
Content	6 different experiments out of: equilibrium study of the calcium carbonate system, flocculation, adsorption, oxidation, atomic absorption spectroscopy, ion chromatography, liquid chromatography, sum parameter, and an oral presentation of the student					
Workload	Attendance time: 35 h Preparation/follow-up: 50 h Examination + exam preparation: 35 h					
Literature	Harris, D. C. (2010): Quantitative Chemical Analysis. W. H. Freeman and Company, New York. Crittenden J. C. et al. (2005); Water Treatment – Principles and Design, Wiley & Sons, Hoboken. Patnaik P. (2010), Handbook of Environmental Analysis: Chemical Pollutants in Air, Water, Soil, and Solid Wastes. CRC Press. Wilderer, P. (2011). Treatise on Water Science, Four-Volume Set, 1st Edition; Volume 3: Aquatic Chemistry and Biology. Elsevier, Oxford. Lecture Notes in ILIAS					

Process Engineering in Wastewater Treatment

Module Code	PA321
Responsible Lecturer	**Prof. h.c. Erhard Hoffmann**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Water Technologies and Urban Water Cycle' MSc *Civil Engineering*
Instruction Language	English
Duration	1 semester
Module Frequency	Each winter semester
Learning Controls/Exams	Written exam, 60 min
Special Features of the Exam	None
Grade	Grade of the written exam
Requirements	None
Recommendations	Module 'Urban Water Infrastructure and Management (AF301)'
Conditions	None
Learning Outcomes	Students acquire knowledge about typical techniques in wastewater treatment at local and international level. They are able to perform a technical evaluation and describe dimensioning approaches taking into consideration legal boundary conditions. Students analyze, evaluate and optimize operation of plant technologies. They focus on energy-efficient plant designs considering the most relevant factors affecting the total costs. Students can analyze the situation in emerging and developing countries making a comparison with that in industrialized countries. Based on that, they are able to develop water-related management strategies.

Courses	**Title**	**Type**	**HPW**	**Semester**		**Lecturer**
	Municipal Wastewater Treatment	L/T	2	W		E. Hoffmann
	International Sanitary Engineering	L/T	2	W		E. Hoffmann

Content	**Municipal Wastewater Treatment:** Students gain deep knowledge about design and operation of typical process technologies in municipal wastewater treatment in Germany. Following processes are covered: - Different activated sludge processes - Anaerobic technologies and energy-recovery systems - Filtration technologies - Wastewater disinfection and pathogen removal - Chemical and biological phosphorus removal - Micro-pollutants removal - Resource management and energy efficiency **International Sanitary Engineering:** Students get acquainted with the design and operation used for wastewater treatment at international level. They analyze, evaluate and take decisions when new and more holistic oriented methods can be implemented. Following topics are covered: - Activated sludge processes - Trickling filters and rotating biological contactors - Treatment ponds - Retention soil filter / Wetlands - UASB/EGSB/Anaerobic filter - Decentralized versus centralized systems - Material flow separation - Energy-recovery from wastewater - Waste management
Workload	Attendance time: 60 h Preparation/follow-up: 60 h Examination + exam preparation: 60 h
Literature/ Learning Materials	Imhoff, K. u. K.R. (1999) Taschenbuch der Stadtentwässerung, 29. Aufl., Oldenbourg Verlag, München, Wien ATV-DVWK (1997) Handbuch der Abwassertechnik: Biologische und weitergehende Abwasserreinigung, Band 5, Verlag Ernst & Sohn, Berlin ATV-DVWK(1997) Handbuch der Abwassertechnik: Mechanische Abwasserreinigung, Band 6, Verlag Ernst & Sohn, Berlin Sperling, M.; Chernicaro, C.A.L. (2005) Biological wastewater treatment in warm climate regions, IWA publishing, London Wilderer, P.A., Schroeder, E.D. and Kopp, H. (2004) Global Sustainability - The Impact of Local Cultures. A New Perspective for Science and Engineering, Economics and Politics WILEY-VCH

Wastewater and Storm Water Treatment

Module Code	PA322
Responsible Lecturer	**Prof. h.c. Erhard Hoffmann**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Water Technologies and Urban Water Cycle' MSc *Civil Engineering*
Instruction Language	English
Duration	1 semester
Module Frequency	Each summer semester
Learning Controls/Exams	Examination of other type in the form of a term paper (about 10 pages) and presentation (15 min)
Special Features of the Exam	None
Grade	Grade of the examination of other type
Requirements	None
Recommendations	Module 'Urban Water Infrastructure and Management (AF301)'
Conditions	None
Learning Outcomes	Students get familiar with technical plants for wastewater and storm water treatment. They can explain operating principles of individual system components as well as assess their suitability for specific applications and apply basic dimensioning approaches.

Courses	Title	Type	HPW	Semester		Lecturer
	Process Technologies in Water Supply, Storm Water Treatment and Wastewater Disposal	L/T	4		S	S. Fuchs, E. Hoffmann
Content	Guided visits, description and evaluation of different water treatment plants: - Storm water sedimentation tanks - Storm water overflow - Retention soil filters - Sewage treatment plants Dimensioning approaches for the design of storm water treatment facilities.					
Workload	Attendance time: 60 h Preparation/follow-up: 30 h Term paper and presentation: 90 h					
Literature/ Learning Materials	Gujer, W. „Siedlungswasserwirtschaft“, Springer, Berlin 3.Aufl., 2007 Grigg, N, S „Water, Wastewater, and Stormwater Infrastructure Management“, Second Edition (English) Francis and Taylor 2012					

Industrial Water Management

Module Code	PA323
Responsible Lecturer	**Prof. h.c. Erhard Hoffmann**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Water Technologies and Urban Water Cycle' MSc *Civil Engineering*
Instruction Language	English
Duration	2 semesters
Module Frequency	Each semester
Examinations/Partial Deliveries	Oral exam, 30 min. Internal prerequisite for the exam: Written report on the laboratory work (about 10 pages)
Special Features of the Exam	None
Grade	Grade of the oral exam
Requirements	None
Recommendations	None
Conditions	None
Learning Outcomes	Students acquire knowledge about techniques for wastewater treatment in industrial production processes and based on it, they can explain functioning principles of the techniques. Students are able to assess wastewater constituents from industrial effluents and its emissions on the basis of legal regulations. They can analyze arising problems in the industrial wastewater treatment and select appropriate methods for emission reduction and water recycling.

Courses	Title	Type	HPW	Semester		Lecturer
	Cleaner Production	L/T	2		S	E. Hoffmann
	Adapted Technologies	L/T	2	W		E. Hoffmann
Content	In this module, different types of industrial wastewater (e.g. leather, paper, metal industries) are considered and studied. Customized chemical, physico-chemical and, if necessary, biological treatment processes are presented and discussed.					
Workload	Attendance time: 60 h Preparation/follow-up: 40 h Lab report: 30 h Examination + exam preparation: 50 h					
Literature/ Learning Materials	Lecture notes Rüffer, H; Rosenwinkel, K.-H. (1991) Handbuch der Industrieabwasserreinigung, Oldenbourg-Verlag, München Metcalf and Eddy (2003) Wastewater Engineering – Treatment and Reuse, McGraw-Hill, New York					

Water Distribution Systems/ Wasserverteilungssysteme

Module Code	PA621
Responsible Lecturer	**NN**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Water Technologies and Urban Water Cycle' MSc *Civil Engineering*
Instruction Language	German/English
Duration	1 semester
Module Frequency	Each winter semester, starting in 2017
Learning Controls/Exams	Oral exam, 30 min. Prerequisite for the exam is a project work with written report (15 pages) and presentation.
Special Features of the Exam	None
Grade	The overall grade of the module corresponds to the grade of the oral exam.
Requirements	None
Recommendations	Hydromechanics (particularly pipe hydraulics)
Conditions	None
Learning Outcomes	Students will have profound knowledge of the components and operational requirements of water supply systems. They are enabled to plan, design and optimize water distribution systems. They are capable to critically analyze concepts and designs based on their knowledge. Participants are able to set up and apply numerical models of water distribution systems for planning and analysis. Students have competences in work organization, presentation and discussion of results.

Courses	Title	Type	HPW	Semester		Lecturer
	Water Distribution Systems/ Wasserverteilungssysteme	L/T	2/2	W		NN
Content	The module covers the following topics: - Fundamentals of water distribution - Fundamentals of water distribution system modeling - Introduction to the software Epanet (water distribution system model) and ArcGIS (geographic information system) - Water demand - Water losses - Calibrating a water distribution system model - Designing pipe networks, storage tanks and pump stations - Application of the technical standards (DVGW) The participants apply the theoretical knowledge to analyze and design an exemplary water distribution network.					
Workload	Attendance time: 60 h Preparation/follow-up: 30 h Project work: 60 h Examination + exam preparation: 30 h					
Literature/ Learning Materials	Mutschmann und Stimmelmayr (2007). Taschenbuch der Wasserversorgung, 14. Auflg., Vieweg. Walski, T. M., Chase, D. V., Savic, D. A., Grayman, W., Beckwith, S. und Koelle, E. (2003). Advanced Water Distribution Modeling Management, Haestad Methods Inc., Waterbury. Course materials (in German and English)					

Biofilm Systems

Module Code	PA224
Responsible Lecturer	**Prof. Dr. Harald Horn**
Level	4
ECTS Credits	4
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Water Technologies and Urban Water Cycle' MSc *Chemical Engineering*
Instruction Language	English
Duration	1 semester
Module Frequency	Each summer semester
Examinations/Partial Deliveries	Oral exam, 20 min
Special Features of the Exam	None
Grade	Grade of the oral exam
Requirements	None
Recommendations	None
Conditions	None
Learning Outcomes	Students can describe the structure and function of biofilms in natural habitats as well as in technical systems. They can explain the major influencing factors and processes for the formation of biofilms. They are familiar with techniques for visualizing biofilm structures as well as with models for simulating biofilm growth. They are able to select appropriate methods for the analysis of biofilms and to evaluate the habitat conditions.

Courses	Title	Type	HPW	Semester		Lecturer
	Biofilm Systems	L	2		S	H. Horn, J. Gescher, A. Hille-Reichel, M. Wagner
Content	Microorganisms typically organize in the form of biofilms in technical and natural aquatic systems. However, biofilms are not only accumulated microorganisms at interfaces: They are bound together by a matrix of extracellular polymeric substances (EPS). In this course, the structure and function of biofilms in different natural habitats and technical applications (biofilm reactors, biofilms in natural waters, biofouling in technical systems and biofilms for power generation in microbial fuel cells) are presented and discussed. Biofilm growth and abrasion as well as models for the simulation of these processes are introduced. Furthermore, microscopic techniques for the visualization of biofilm structures are presented.					
Workload	Attendance time: 30 h Preparation/follow-up: 30 h Examination + exam preparation: 60 h					
Literature/ Learning Materials	Lecture notes in ILIAS					

2.5 Profile B: Fluid Mechanics & Hydraulic Engineering

Environmental Fluid Mechanics

Module Code	PB421
Responsible Lecturer	**Prof. Dr. Olivier Eiff**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Fluid Mechanics and Hydraulic Engineering' MSc *Civil Engineering*
Instruction Language	English
Duration	1 semester
Module Frequency	Each winter semester
Learning Controls/Exams	Written exam, 90 min
Special Features of the Exam	None
Grade	Grade of the written exam
Requirements	Module 'Advanced Fluid Mechanics (AF401)'
Recommendations	Module 'Analysis of Turbulent Flows (PB521)'
Conditions	None
Learning Outcomes	Students identify fundamental hydrodynamic processes in the natural environment in water and air applications and solve related problems. They can relate the observed phenomena to fundamental principles of hydrodynamics and to the specific nature of the flow conditions. They can critically evaluate the different models and approximations made to obtain solutions and predictions and can make first estimates.

Courses	Title	Type	HPW	Semester		Lecturer
	Environmental Fluid Mechanics	L/T	3/1	W		O. Eiff
Content	This module covers the fundamental concepts and flow models of environmental fluid mechanics in both water and air. The topics include turbulence structure in rivers and open channels, diffusion and dispersion, atmospheric boundary layers, internal waves, instabilities and mixing, stratified turbulence, buoyant jets and plumes.					
Workload	Attendance time: 60 h Preparation/follow-up: 60 h Examination + exam preparation: 60 h					
Literature/ Learning Materials						

Analysis of Turbulent Flows

Module Code	PB521
Responsible Lecturer	**Prof. Dr. Markus Uhlmann**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Fluid Mechanics and Hydraulic Engineering' MSc *Civil Engineering* MSc *Mechanical Engineering*
Instruction Language	English
Duration	2 semesters, starting in summer semester
Module Frequency	Each summer semester
Learning Controls/Exams	Oral exam, 45 min
Special Features of the Exam	None
Grade	Grade of the oral exam
Requirements	None
Recommendations	Basic fluid mechanics (experience in working with the Navier-Stokes equations) Mathematics (analysis – partial differential equations, Fourier series, vectors/tensors, matrices and eigenvalues; statistics) Knowledge in programming with Matlab is recommended; otherwise it is strongly recommended to participate in the course 'Introduction to Matlab (CC772)'.
Conditions	None
Learning Outcomes	Participants are able to describe the characteristics of turbulent flows, and to quantify their effect upon the transport rates of momentum, heat and mass. They are aware of the problems associated with computationally determining turbulent flow quantities. With this knowledge, they are able to weigh the pros and cons of the different modeling approaches; they are further able to choose an appropriate approach for a given application. Participants have the ability to critically evaluate the expected outcome of a range of turbulence models with respect to their predictive capabilities and the required computational effort.

Courses	Title	Type	HPW	Semester		Lecturer
	Fluid Mechanics of Turbulent Flows	L	2		S	M. Uhlmann
	Modeling of Turbulent Flows – RANS and LES	L	2	W		M. Uhlmann
Content	The present module gives a general introduction to the analysis of turbulent flows. The mathematical description of the physics of turbulence is successively developed, i.e. the properties of the conservation laws, the required mathematical tools and the most useful modeling approaches for fluids engineering problems. The course **Fluid Mechanics of Turbulent Flows** presents the phenomenology of turbulent flows, introduces the statistical description of turbulent flow processes, discusses the characteristics of free and wall-bounded shear flows, and presents an analysis of the turbulent energy cascade. In the course **Modeling of Turbulent Flows - RANS and LES**, first the statistical approach to turbulence modeling, based upon Reynolds averaging (RANS) is presented, starting with the simplest algebraic model and ranging up to Reynolds stress transport models. Furthermore, an introduction to the concept of large-eddy simulation (LES) is given.					
Workload	Attendance time: 60 h Preparation/follow-up: 60 h Examination + exam preparation: 60 h					
Literature/ Learning Materials						

Advanced Computational Fluid Mechanics

Module Code	PB522
Responsible Lecturer	**Prof. Dr. Markus Uhlmann**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Fluid Mechanics and Hydraulic Engineering' MSc *Civil Engineering*
Instruction Language	English
Duration	1 semester
Module Frequency	Each summer semester
Examinations/Partial Deliveries	Partial exam 'Numerical fluid mechanics II' (3 CP): oral exam, 30 min. Partial exam 'Parallel programming techniques for engineering problems' (3 CP): written exam, 60 min.
Special Features of the Exam	None
Grade	Weighted average of the grades of the partial exams according to credit points
Requirements	Module 'Numerical Fluid Mechanics (AF501)'
Recommendations	Programing skills in at least one compiler language (C,C++, FORTRAN or equivalent)
Conditions	None
Learning Outcomes	Students are able to numerically solve simplified flow problems based upon the Navier-Stokes equations in an independent fashion. This involves the design of a solution method, the analysis of its properties (concerning stability, precision, computational effort), the algorithmic implementation, the validation with respect to appropriate test cases, and the final documentation of the results. Furthermore, participants of this course are enabled to judge techniques for the use of massively parallel computer systems to solve fluid mechanics problems as to their efficiency and applicability. They are capable of applying the appropriate parallel programming techniques to selected model problems.

Courses	Title	Teaching mode	Hours/ week	Semester		Lecturer
	Numerical Fluid Mechanics II	L/T	1/1		S	M. Uhlmann
	Parallel Programing Techniques for Engineering Problems	L/T	1/1		S	M. Uhlmann
Content	In the present module, advanced skills in the numerical solution of fluid mechanics problems are imparted, building upon the material of the course **Numerical Fluid Mechanics II**. Here, various numerical solution methods for the time-dependent Navier-Stokes equations in several spatial dimensions are demonstrated with the aid of practical examples. This includes the following aspects: coupling and decoupling of velocity and pressure fields in incompressible flows, numerical treatment of discontinuities (shock waves, hydraulic jumps), computation of scalar transport, numerical tracking of inertial particles, linear stability analysis. The course **Parallel Programing Techniques for Engineering Problems** conveys the fundamental programming concepts for massively-parallel computer systems. First, the common parallel computer architectures and the most widely used programming paradigms are introduced. Then techniques for implementing standard algorithms of numerical fluid mechanics (and other disciplines involving field problems) are presented, analyzed and practiced with the aid of the *Message Passing Interface (MPI)* standard.					
Workload	Attendance time: 60 h Preparation/follow-up: 60 h Examination + exam preparation: 60 h					
Literature/Learning Materials						

Technical Hydraulics/ Technische Hydraulik

Module Code	PB431
Responsible Lecturer	**Dr.-Ing. Cornelia Lang**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Fluid Mechanics and Hydraulic Engineering' MSc *Civil Engineering*
Instruction Language	German
Duration	1 semester
Module Frequency	Each summer semester
Learning Controls/Exams	Written exam, 100 min
Special Features of the Exam	None
Grade	Grade of the written exam
Requirements	None
Recommendations	Basic knowledge of hydromechanics
Conditions	None
Learning Outcomes	- See German version

Courses	Title	Type	HPW	Semester		Lecturer
	Steady and Unsteady Operation of Hydraulic Systems/ Stationärer und instationärer Betrieb von hydraulischen Anlagen	L/T	2/2		S	C. Lang
Content	- See German version					
Workload	Attendance time: 60 h Preparation/follow-up: 60 h Examination + exam preparation: 60 h					
Literature/ Learning Materials	- See German version					

Experimental Hydraulics and Measuring Techniques/ Versuchswesen und Strömungsmesstechnik

Module Code	PB641
Responsible Lecturer	**Dr.-Ing. Frank Seidel**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Fluid Mechanics and Hydraulic Engineering' MSc *Civil Engineering*
Instruction Language	German
Duration	1 semester
Module Frequency	Each winter semester
Examinations/Partial Deliveries	Partial exam 'Measurement Techniques in Flows' (3 CP): oral, 30 min Partial exam 'Hydraulic Experiments II' (3 CP): EoT (graded paper, 10 pages)
Special Features of the Exam	None
Grade	Weighted average of the grades of the partial exams according to credit points
Requirements	None
Recommendations	Module 'Experiments in Fluid Mechanics (CC 471)' Hydraulic lab practice
Conditions	None
Learning Outcomes	Students are able to describe the principles of different flow measurement methods and combine this information with the basics of today's flow measurement technology. They have basic knowledge about the structure and can analyze the suitability of measurement methods and set application boundaries. Students have basic knowledge about experimentation in hydraulics. They know the similarity mechanical requirements and assign them to the hydromechanical basics. Students are able to analyze applications in the field of multiphase hydraulics and select suitable model concepts. They can present their own thoughts and ideas in a structured manner and discuss the themes with specialists.

<table>
<tr><td>Courses</td><td>Title</td><td>Type</td><td>HPW</td><td colspan="2">Semester</td><td>Lecturer</td></tr>
<tr><td></td><td>Flow Measuring Techniques/ Strömungsmesstechnik</td><td>L/T</td><td>1/1</td><td>W</td><td></td><td>B. Ruck</td></tr>
<tr><td></td><td>Experimental Hydraulics II/ Wasserbauliches Versuchswesen II</td><td>L/T</td><td>1/1</td><td>W</td><td></td><td>F. Nestmann, F. Seidel</td></tr>
<tr><td>Content</td><td colspan="6">In this module, the following topics will be discussed in depth:

Flow Measuring Techniques:
- Basic equations of fluid mechanics
- Relevant metrics
- Pressure sensors
- Mechanical measuring methods
- Electrical measuring methods
- Acoustic measuring methods
- Optical measuring methods

Experimental Hydraulics II:
- Models with movable beds
- Experiments related to multiphase flow problems (water-air, water-solid)
- Applications and their boundaries</td></tr>
<tr><td>Workload</td><td colspan="6">Attendance time: 60 h
Preparation/follow-up: 60 h
Examination + exam preparation: 60 h</td></tr>
<tr><td>Literature/ Learning Materials</td><td colspan="6"></td></tr>
</table>

Hydraulic Structures

Module Code	PB631
Responsible Lecturer	**Prof. Dr.-Ing. Franz Nestmann**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Fluid Mechanics and Hydraulic Engineering' MSc *Civil Engineering*
Instruction Language	Groundwater Flow around Structures: English Interaction Flow and Hydraulic Structures: German
Duration	2 semesters
Module Frequency	Each semester
Examinations/Partial Deliveries	Partial exam 'Groundwater Flow around Structures' (3 CP): Oral exam, 30 min. Partial exam on 'Interaction Flow and Hydraulic Structures' (3 CP): Oral exam, 30 min.
Special Features of the Exam	None
Grade	Weighted average of the grades of the partial exams according to credit points
Requirements	None
Recommendations	None
Conditions	None
Learning Outcomes	Students are able to analyze and calculate steady and unsteady flow forces on hydraulic structures. They can describe groundwater flow processes and derive flow parameters with common measurement calculations. Based on the acquired knowledge, they can analyze concepts for preventing groundwater-related structural damage in a critical manner. Students characterize and categorize flow-induced structural vibrations. They can apply their knowledge to application examples.

<table>
<tr><td rowspan="3">Courses</td><td>Title</td><td>Type</td><td>HPW</td><td colspan="2">Semester</td><td>Lecturer</td></tr>
<tr><td>Groundwater Flow around Structures</td><td>L/T</td><td>1/1</td><td></td><td>S</td><td>F. Nestmann</td></tr>
<tr><td>Interaction Flow – Hydraulic Structures/ Wechselwirkung Strömung - Wasserbauwerke</td><td>L/T</td><td>1/1</td><td>W</td><td></td><td>C. Lang</td></tr>
<tr><td>Content</td><td colspan="6">In this module, the following topics are discussed in depth:

Groundwater Flow around Structures:
- Potential theory, groundwater flow
- Phreatic, leakage paths
- Hydraulic heave
- Structural adjustment
- Sealing systems

Interaction Flow - Hydraulic Structures:
Special attributes of sealing mechanisms (weirs, flood sluices, gates) will be introduced in hydraulic steel structures and their structural design and calculating of load are discussed.
Topics covered:
- Determination of hydrostatic and hydrodynamic flow forces
- Basics of design
- Overview of sealing mechanisms: Flood sluices, weirs, gates
- Flow-induced structural vibrations
- Cavitation
- Gaskets
- Corrosion prevention</td></tr>
<tr><td>Workload</td><td colspan="6">Attendance time: 60 h
Preparation/follow-up: 60 h
Examination + exam preparation: 60 h</td></tr>
<tr><td>Literature/Learning Materials</td><td colspan="6">Erbisti, P.C.F., 2004, Design of Hydraulic Gates, Balkema Pub., Tokyo
Naudascher; E, 1991, Hydrodynamic Forces, Balkema Pub., Rotterdam
Skript: C. Lang, Interaktion Strömung - Wasserbauwerk</td></tr>
</table>

Numerical Flow Modeling in Hydraulic Engineering/ Numerische Strömungsmodellierung im Wasserbau

Module Code	PB651
Responsible Lecturer	**Dr.-Ing. Peter Oberle**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Fluid Mechanics and Hydraulic Engineering' MSc *Civil Engineering*
Instruction Language	German
Duration	1 semester
Module Frequency	Each winter semester
Examinations/Partial Deliveries	Oral exam, 20 min
Special Features of the Exam	None
Grade	Grade of the written exam
Requirements	None
Recommendations	Basic knowledge of hydrology, hydraulic engineering and water management as well as channel hydraulics
Conditions	None
Learning Outcomes	- See German version

Courses	Title	Teaching mode	Hours/ week	Semester		Lecturer
	Numerical Flow Modeling in Hydraulic Engineering/ Numerische Strömungs-modellierung im Wasserbau	L/T	2/2	W		P. Oberle, M. Musall
Content	- See German version					
Workload	Attendance time: 60 h Preparation/follow-up: 60 h Examination + exam preparation: 60 h					
Literature/ Learning Materials	Lecture notes					

Hydro Power Engineering/ Energiewasserbau

Module Code	PB653
Responsible Lecturer	**Dr.-Ing. Peter Oberle**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Fluid Mechanics and Hydraulic Engineering' MSc *Civil Engineering*
Instruction Language	Teaching language: German, teaching material: English
Duration	1 semester
Module Frequency	Each summer semester
Examinations/Partial Deliveries	Oral exam, 20 min
Special Features of the Exam	None
Grade	Grade of the oral exam
Requirements	None
Recommendations	Hydraulic Engineering and Water Management
Conditions	None
Learning Outcomes	Students are able to describe the different turbine types and can define selection criteria for their usage. They are able to reproduce the basic approaches in the planning and design of hydropower plants and to make own calculations to select turbines. They can select and apply the necessary tools in a methodical matter. Students are able to discuss the current political conditions in terms of energy policy with other students and support their personal opinion on these issues with technical arguments.

Courses	Title	Teaching mode	Hours/ week	Semester		Lecturer
	Hydro Power Engineering/ Energiewasserbau	L/T	3/1		S	P. Oberle
Content	The course explains the technical basics for the planning and design of hydropower plants. It covers the structural features of river power plants and high-pressure systems, the functions and selection criteria of different types of turbines and the electrical aspects of the plant. In addition, environmental issues and the political framework of hydropower will be discussed. The lectures are completed by current project studies and excursions.					
Workload	Attendance time: 60 h Preparation/follow-up: 60 h Examination + exam preparation: 60 h					
Literature/ Learning Materials	Lecture Notes Giesecke J., Mosonyi E., 2005, Wasserkraftanlagen, Planung, Bau und Betrieb, Springer Verlag, Berlin					

Waterway Engineering/ Verkehrswasserbau

Module Code	PB655
Responsible Lecturer	**Dr.-Ing. Andreas Kron**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Fluid Mechanics and Hydraulic Engineering' MSc *Civil Engineering*
Instruction Language	Teaching language: German, teaching material: English
Duration	1 semester
Module Frequency	Each summer semester
Examinations/Partial Deliveries	Oral exam, 20 min Ungraded learning control (seminar paper) as prerequisite for the exam
Special Features of the Exam	None
Grade	Grade of the oral exam
Requirements	None
Recommendations	None
Conditions	None
Learning outcomes	Students are knowledgeable about the various types of navigable waterways and their hydraulic structures. They are able to describe and apply the hydraulic basics for the design of these hydraulic structures and the interaction between ship and waterway. Students can assign the tasks and responsibilities of waterway engineering to the administrative structure of the waterways and shipping.

Courses	Title	Type	HPW	Semester		Lecturer
	Waterway Engineering/ Verkehrswasserbau	L/T	2/2		S	A. Kron
Content	- Inland waterways - Types of navigation locks and ship lifts - Hydraulics and design of navigation locks and ship lifts - Reinforcement of embankments, banks and beds - Interaction ship-waterway					
Workload	Attendance time: 60 h Preparation/follow-up: 30 h Seminar paper: 30 h Examination + exam preparation: 60 h					
Literature/ Learning Materials						

Flow and Sediment Dynamics in Rivers/ Fließgewässerdynamik und Feststofftransport

Module Code	PB633
Responsible Lecturer	**Dr.-Ing. Frank Seidel**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Fluid Mechanics and Hydraulic Engineering' MSc *Civil Engineering*
Instruction Language	Flow Behavior of Rivers: English Morphodynamics: German and English
Duration	1 semester
Module Frequency	Each summer semester
Examinations/Partial Deliveries	Oral exam, 30 min Ungraded learning control as a prerequisite for the exam: Seminar paper in the course 'Flow Behavior of Rivers' (about 15 pages)
Special Features of the Exam	None
Grade	Grade of the oral exam
Requirements	None
Recommendations	None
Conditions	None
Learning Outcomes	Students are able to name and explain the basic relationships and interactions between topography, flow and morphodynamics in natural streams. They can describe and apply the respective design approaches. Students are able to analyze the engineering design methods and combine this information with the basics of hydromechanics. They actively and independently inform themselves about the latest state in technology and can use adequate methods to solve engineering problems. They can present their findings and discuss the themes with specialists.

Courses	Title	Type	HPW	Semester		Lecturer
	Flow Behavior of Rivers	L/T	1/1		S	F. Seidel, S Wunder
	Morphodynamics/ Morphodynamik	L/T	1/1		S	F. Nestmann
Content	In this module, the following topics are discussed in depth: - Geomorphic cycle - Space-time approach in morphology - Anthropogenic influences on streams - Vegetation hydraulics - Approaches to interactions - Bed load and sediment management in streams - Practical examples					
Workload	Attendance time: 60 h Seminar paper: 30 h Preparation/follow-up: 45 h Examination + exam preparation: 45 h					
Literature/ Learning Materials						

Water Resources Management – Feasibility Study/ Projektstudium: Wasserwirtschaftliche Planungen

Module Code	PB661
Responsible Lecturer	**Dr.-Ing. Frank Seidel**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Fluid Mechanics and Hydraulic Engineering' MSc *Civil Engineering*
Instruction Language	German
Duration	1 semester
Module Frequency	Each winter semester
Learning Controls/Exams	Examination of other type, consisting of a written assignment (about 15 pages) and a presentation (15 min.)
Special Features of the Exam	None
Grade	Grade of the examination of other type
Requirements	None
Recommendations	Module 'Flow and Sediment Dynamics in Rivers (PB633)'
Conditions	None
Learning Outcomes	- See German version

Courses	Titel	Art	HPW	Semester		Dozent/in
	Project Studies in Water Resources Management/ Projektstudium: Wasserwirtschaftliche Planungen	L/T	2/2	W		F. Nestmann, F. Seidel
Content	- See German version					
Workload	Attendance time: 30 h Preparation/follow-up: 30 h Examination + exam preparation (project report): 120 h					
Literature/ Learning Materials						

2.6 Profile C: Environmental System Dynamics & Management

Thermodynamics of Environmental Systems

Module Code	PC741
Responsible Lecturer	**Dr.-Ing. Uwe Ehret**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Environmental System Dynamics and Management' MSc *Civil Engineering* MSc *Geoecology*
Instruction Language	English
Duration	1 semester
Module Frequency	Each winter semester
Examinations/Partial Deliveries	Examination of other type: Assignments (programming exercise and short report of about 2 pages) and final take-home exam (about 10 pages)
Special Features of the Exam	None
Grade	The module grade corresponds to the grade of the examination of other type, which is calculated from the points of the assignments and take-home exam
Requirements	None
Recommendations	Knowledge of programming with Matlab. Otherwise, it is strongly recommended to participate in the course 'Introduction to Matlab (CC772)'.
Conditions	None
Learning Outcomes	Students are able to describe environmental systems as hierarchical subsystems of the earth system and to name the borders, state variables and processes of selected environmental systems with respect to water- and energy transport. Students know the fundamental laws of thermodynamics and can explain why and how these form the foundation to describe environmental system dynamics in general. Students know the basic mechanisms of self-organization. They can explain how environmental systems can move away from thermodynamic equilibrium states by the buildup of structure. Students are able to set up computer models to simulate water- and energy dynamics in simple environmental systems. Students are able to solve problems and to present the results in teamwork.

Courses	Title	Teaching mode	Hours/ week	Semester		Lecturer
	Thermodynamics of Environmental Systems	L/T	2/2	W		U. Ehret
Content	- Fundamentals of environmental systems theory and environmental modeling (system boundaries, system states, deterministic, complex, and chaotic systems) - Energy and entropy - Work and power, dissipation and thermodynamic equilibrium - The four laws of thermodynamics - Carnot limit - Fundamentals of self-organization (positive and negative feedbacks, order parameters) - Entropy in thermodynamics and information theory: similarities and differences - Independent setup of computer models to simulate the water- and energy-related dynamics of environmental systems based on simple numerical schemes in the form of assignments Preparation of assignments and presentation in small groups					
Workload	Attendance time: 60 h Preparation/follow-up: 20 h Homework, presentations: 60 h Take-home exam: 40 h					
Literature/ Learning Materials	Prigogine, I. (1989): What is entropy? Naturwissenschaften, 76, 1-8, 10.1007/bf00368303. Kleidon, A. (2010): Life, hierarchy, and the thermodynamic machinery of planet Earth, Physics of Life Reviews, 7, 424-460.					

Management of Water Resources and River Basins

Module Code	PC721
Responsible Lecturer	**Dr.-Ing. Uwe Ehret**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Environmental System Dynamics and Management' MSc *Civil Engineering* MSc *Geoecology*
Instruction Language	English
Duration	1 semester
Module Frequency	Each summer semester
Examinations/Partial Deliveries	Examination of other type: Assignments (short reports of about 2 pages) and final take-home exam (application of a hydrological model and a report of about 15 pages)
Special Features of the Exam	None
Grade	The module grade corresponds to the grade of the examination of other type, which is calculated from the points of the assignments and take-home exam
Requirements	None
Recommendations	Knowledge of hydrology and engineering hydrology
Conditions	None
Learning Outcomes	Students are able to identify the components of tasks related to Water Management. They are able to formulate solutions for these tasks based on the principles of Integrated Water Resources Management (IWRM). Students are familiar with the principles, methods and limitations of environmental systems modeling and are able to set up and apply water balance models for given tasks of Water Resources Management. They are able to interpret the results and quantify and evaluate the related uncertainties. Students are able to solve problems and to present the related results in teamwork.

Courses	Title	Type	HPW	Semester		Lecturer
	Management of Water Resources and River Basins	L/T	2/2		S	U. Ehret
Content	- Definition, scope and examples of Integrated River Basin Management - Methods for Multi-Objective Decision Making (Utility Matrix) - Hydrological Modeling: Environmental Systems Theory, Calibration and Validation, Sensitivity and Uncertainty Analysis - Methods of Engineering Hydrology - Computer-based application of hydrological models (HBV, Larsim): manual and automated calibration, Monte-Carlo-based uncertainty estimation, identification of design storm hydrographs Preparation of assignments and presentation in small groups.					
Workload	Attendance time: 60 h Preparation/follow-up: 20 h Homework, presentations: 60 h Take-home exam: 40 h					
Literature/ Learning Materials						

Transport and Transformation of Contaminants in Hydrological Systems

Module Code	PC725
Responsible Lecturer	**Prof. Erwin Zehe**
Level	4
ECTS Credits	9
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Environmental System Dynamics and Management' MSc *Geoecology*
Instruction Language	English
Duration	1 semester
Module Frequency	Each summer semester
Examinations/Partial Deliveries	Oral exam, 30 min (6 CP) Ungraded learning controls as a prerequisite for the exam (3 CP): Report (about 10 pages) on lab experiment and data analysis
Special Features of the Exam	None
Grade	Grade of the oral exam
Requirements	None
Recommendations	Module 'Water and Energy Cycles (AF701)' Module 'Experimental Hydrology (PC731)' Knowledge of programming with Matlab. Otherwise, it is strongly recommended to participate in the course 'Introduction to Matlab (CC772)'
Conditions	None
Learning Outcomes	Students are able to explain processes of transport and decomposition related to nutrients and pollutants in surface runoff and in the unsaturated zone of rural catchments. Students are able to independently apply analytical and process-based models: estimation of model parameters from field investigations, estimation of water- and substance fluxes and balance in the critical zone, statements on the risks related to contaminant mobilization in natural soils. Students are able to evaluate the limits of applicability of modeling approaches in natural, heterogeneous soils.

Courses	Title	Teaching mode	Hours/ week	Semester		Lecturer
	Transport and Transformation of Contaminants in Hydrological Systems	L/T	2/3		S	E. Zehe, J. Wienhöfer
Content	Transport processes in the unsaturated zone related to infiltration, surface runoff, and movement of soil water: - Advective-dispersive transport in homogeneous and heterogeneous soils - Particulate transport by erosion - Adsorption - Chemical and microbial processes of reaction and decay in soils - Modeling contaminant transport (e.g. pesticides) in soils using analytical models - Risk assessment for pesticides in soils (transport, residence times, adsorption, decay) - Estimation of model parameters from field exploration - Parameterization of adsorption isotherms - Breakthrough curves Lab experiments: - Setup of a undisturbed soil column, and conduction of transport experiments Computer exercise - Simulation of water and substance transport with process-based models - Independently conducted risk-assessments for pesticides using simple simulation techniques					
Workload	Attendance time: 75 h Preparation/follow-up: 45 h Report (uLC): 90 h Examination + exam preparation: 60 h					
Literature/Learning Materials	Jury, W. and Horton, R. (2004): Soil physics. John Wiley Hillel, D. (1995): Environmental Soil Physics. Academic Press Fritsche, W. (1998) Umweltmikrobiologie, Grundlagen und Anwendungen. Gustav Fischer Verlag, 248pp.					

Experimental Hydrology

Module Code	PC731
Responsible Lecturer	**Dr. Jan Wienhöfer**
Level	4
ECTS Credits	9
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Environmental System Dynamics & Management' MSc *Geoecology*
Instruction Language	English
Duration	1 semester
Module Frequency	Each summer semester
Examinations/Partial Deliveries	Partial Exam 'Hydrological Measurements in Environmental Systems' (6 CP): Examination of other type - written report (about 15 pages) and presentation of the results of laboratory and field work Partial Exam 'Isotope Hydrology' (3 CP): Examination of other type - written report (about 10 pages) and presentation of the results of laboratory and field work
Special Features of the Exam	None
Grade	Weighted average of the grades of the partial exams according to credit points
Requirements	None
Recommendations	Knowledge of hydrology
Conditions	None
Restrictions	The courses in this module require a minimum number of 6 and a maximum number of 30 participants. Please register online (in exceptional cases via e-mail to the responsible lecturer). Participants are selected according to their year of study and in the following order: Students of *Water Science and Engineering*, students of *Geoecology*, other.
Learning Outcomes	Students can name the processes of the terrestrial water cycle and explain their influence on catchment-scale landscape evolution. Students know and understand measurement principles for catchment properties, catchment states, and water fluxes. They are able to independently plan and conduct measurements on various scales (soil column, plot, hillslope, catchment) in the field and the laboratory. Students can analyze observation data with statistical methods, and are able to quantify and evaluate the related uncertainties. Students are able to work and present their results as a team.

Courses	Title	Type	HPW	Semester		Lecturer
	Hydrological Measurements in Environmental Systems	L/T/P	4		S	J. Wienhöfer, U. Ehret
	Isotope Hydrology	L/T	2		S	J. Klaus
Content	**Hydrological Measurements in Environmental Systems:** - Fundamentals of environmental systems theory and environmental observations (scales, uncertainties) - Literature study and discussion related to environmental monitoring - Hydrological measurement devices in field and laboratory: Discharge, soil moisture, infiltration, matric potential, ground water - Statistical data analysis and error analysis **Isotope Hydrology:** - Fundamentals of isotope hydrology of ^{2}H and ^{18}O in the water cycle - Application examples and literature study on stable water isotopes in (eco-)hydrological process studies - Examples of further isotopes used in hydrological process studies: ^{3}H, ^{17}O, ^{15}N - Analysis and evaluation of isotope data **Both:** Lab and field work (several days) where students conduct hydrological measurements and infiltration- and tracer experiments. They analyze the obtained data statistically. The results are documented in a report, and presented and critically discussed in a colloquium.					
Workload	Attendance time (lecture, lab course and field trip): 100 h Preparation/follow-up: 80 h Report and colloquium: 90 h					
Literature/ Learning Materials	Lecture notes					

River Basin Modeling

Module Code	PC341
Responsible Lecturer	**Dr.-Ing. Stephan Fuchs**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Environmental System Dynamics and Management' MSc *Civil Engineering*
Instruction Language	English
Duration	2 semesters, starting in summer semester
Module Frequency	Each summer semester
Examinations/Partial Deliveries	Examination of other type: Written report (of about 10 pages) and a presentation (about 15 min)
Special Features of the Exam	None
Grade	Grade of the examination of other type
Requirements	None
Recommendations	Module 'Urban Water Infrastructure and Management (AF301)' Module 'Water Ecology (CC371)'
Conditions	None
Learning Outcomes	Students are able to explain the basic relationships between water-driven material cycles in river basins and their budget in aquatic ecosystems. They are able to analyze the impact of anthropogenic activities on water condition and quality. Students gain knowledge regarding transport pathways of substances and biochemical and physical interactions in water bodies in order to formulate mathematical model approaches. Using simulation models, they are able to quantify substance emissions; to predict the impact from external influences on the water quality relevant processes and; to perform different scenario analysis. Students are capable of evaluating model results in terms of their plausibility and uncertainty.

Courses	Title	Type	HPW	Semester		Lecturer
	Mass Fluxes in River Basins	L	2		S	S. Fuchs
	Modeling Mass Fluxes in River Basins	L/T	2	W		
Content	This module provides students with a broad-based understanding of the fundamentals of materials flows (N, P, pollutants) and their relevant transport pathways in river basins. Different modeling approaches for a quantitative description of the processes will be presented. Students receive a single-user version of the simulation tool MoRE (Modeling of Regionalized Emissions). They have to develop and implement their own model in small groups and interpret simulation results.					
Workload	Attendance time: 60 h Preparation/follow-up: 60 h Examination + exam preparation (project work + presentation): 60 h					
Literature/ Learning Materials	Schwoerbel, J. (1993): Einführung in die Limnologie, 7. Aufl., Fischer Verlag, Stuttgart Kummert, R. (1989): Gewässer als Ökosysteme: Grundlagen des Gewässerschutzes, 2. Aufl., Teubner Verlag, Stuttgart Stumm, W.; Morgan, J.J. (1996): Aquatic Chemistry – Chemical equilibria and rates in natural waters, Wiley Interscience, NY					

Aquatic Ecosystems/ Gewässerlandschaften

Modul Code	PC761
Responsible Lecturer	**Dr. Charlotte Kämpf**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Environmental System Dynamics and Management' MSc *Civil Engineering* MSc *Geoecology*
Instruction Language	German (material partly in English)
Duration	1 Semester
Module Frequency	Each winter semester
Examinations/Partial Deliveries	- See German version
Special Features of the Exam	- See German version
Grade	- See German version
Requirements	None
Recommendations	None
Conditions	None
Learning Outcomes	- See German version

Courses	Title	Type	HPW	Semester		Lecturer
	Aquatic Ecosystems/ Gewässerlandschaften	V/S/E	4	W		Ch. Kämpf
Content	- See German version					
Workload	- See German version					
Literature/Learning Materials						

Protection and Use of Riverine Systems

Modul Code	PC762
Responsible Lecturer	**Dr. Charlotte Kämpf**
Level	4
ECTS Credits	6
Study Program	Master *Water Science & Engineering*, compulsory elective module in the profile 'Environmental System Dynamics and Management'
Instruction Language	English
Duration	1 Semester
Module Frequency	Each summer semester
Examinations/Partial Deliveries	Examination of other type: Presentation (about 15 min) and written report (of about 2500 words) on a selected topic Ungraded learning control as prerequisite for the exam: Literature annotation (about 150 words), introductory presentation (about 10 min), and excursion report (about 2 pages)
Special Features of the Exam	None
Grade	Grade of the examination of other type
Requirements	None
Recommendations	None
Conditions	None
Learning Outcomes	Students are able to rank interdisciplinary texts on riverine systems according to their relevance, and formulate relevant questions on this topic. Students can research systematically on a scientific problem. They are able to put the materials in the context of integrated management strategies and current water resources problems to work on solutions for adapting to regional conditions.

Courses	Title	Type	HPW	Semester		Lecturer
	Integrated Water Management	V/E	3		S	S. Fuchs, Ch. Kämpf, F. Nestmann
Content	**Integrated Water Management:** - Planning of water management projects - Adapted technologies (small hydropower systems) - Water distribution networks - Consideration of the geographical, social and political environment **Quality of surface waters:** - Eutrophication, xenobiotics from industry and agriculture; wastewater treatment, threshold values, water protection areas **International Nature Conservation:** - FFH Directive, Natura 2000, wildlife conservation concepts - Renaturation concepts					
Workingload	Attendance time: 40 h (seminar and excursion) Preparation/follow-up: 40 h Exam prerequisite (ungraded learning control): 40 h Exam and exam preparation: 60 h					
Literature/Learning Materials						

Groundwater Management

Module Code	PC561
Responsible Lecturer	**PD Dr. Ulf Mohrlok**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Environmental System Dynamics and Management'
Instruction Language	English
Duration	2 semesters, starting in summer semester
Module Frequency	Each summer semester
Examinations/Partial Deliveries	Partial examination 'Groundwater Hydraulics' (3 CP): oral exam, 30 min Partial examination 'Numerical Groundwater Modeling' (3 CP): examination of other type: project report (10 to 15 pages) and presentation (10 to 15 min.)
Special Features of the Exam	None
Grade	Weighted average of the grades of the partial exams according to credit points
Requirements	None
Recommendations	Fundamental knowledge in fluid mechanics, hydrology, solute transport and numerical methods
Conditions	None
Learning Outcomes	Based on the understanding of the hydrogeologic conditions and the fluid mechanical processes in the subsurface, students can characterize several kinds of groundwater systems. They can quantify the relevant flow and transport processes for different problems of groundwater quantity and quality with simple analytical and numerical methods. Hence, they are able to conceive and evaluate the important relationships for the management of groundwater resources.

Courses	Title	Type	HPW	Semester		Lecturer
	Groundwater Hydraulics	L/T	2		S	U. Mohrlok
	Numerical Groundwater Modeling	T	2	W		U. Mohrlok
Content	**Groundwater Hydraulics:** - Fluid mechanical processes in porous media - Groundwater flow: regional, potential flow, flow towards a well - Processes of groundwater recharge - Solute transport processes - Groundwater management: well catchments, protection zones, groundwater pollution, salt water intrusion **Numerical Groundwater Modeling:** - Numerical methods - Space and time discretization - Accuracy, stability - Working on a study project					
Workload	Attendance time: 75 h Preparation/follow-up: 30 h Term paper (modeling project): 45 h Examination + exam preparation: 30 h					
Literature/Learning Materials	Bear, J. (1979). Hydraulics of Groundwater. McGraw Hill. Chiang, W.-H., Kinzelbach, W. & R. Rausch (1998). Aquifer simulation model for Windows - Groundwater flow and transport modeling, an integrated program. Berlin, D.:Gebrüder Borntraeger. Fetter, C.W. (1999). Contaminant Hydrogeology , 2/e. Upper Saddle River, NJ, U.S.A.: Prentice Hall. Schwartz, F. and H. Zhang (2003). Fundamentals of Ground Water. New York, NY, U.S.A.: John Wiley & Sons.					

Hydrogeology: Field and Laboratory Methods/ Hydrogeologie: Gelände- und Labormethoden

Module Code	PC821
Responsible Lecturer	**Dr. Nadine Göppert**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Environmental System Dynamics and Management' MSc *Applied Geosciences*
Instruction Language	German
Duration	1 semester
Module Frequency	Each summer semester
Learning Controls/Exams	Examination of other type: Presentation in the 'Preparatory Seminar' (3 CP) and written report on the results of the 'Field and Laboratory Exercises' (3 CP)
Special Features of the Exam	None
Grade	Grade of the examination of other type
Requirements	None
Recommendations	Module 'Hydrogeology (AF801)' is strongly recommended.
Conditions	None
Restrictions	The courses in this module have limited capacity. Please register using ILIAS.
Learning Outcomes	- See German version

Courses	Title	Type	HPW	Semester		Lecturer
	Preparatory Seminar/ Vorbereitendes Seminar	S	1		S	N.Göppert T. Liesch J. Klinger
	Field and Laboratory Excercises/ Gelände- und Laborübungen	Ü	2		S	
Content	- See German version					
Workload	Attendance time: 45 h Preparation/follow-up: 65 h Examination + exam preparation: 70 h					
Literature/ Learning Materials	- See German version					

Hydrogeology: Groundwater Modeling/ Hydrogeologie: Grundwassermodellierung

Module Code	PC831
Responsible Lecturer	**Dr. Tanja Liesch**
Level	4
ECTS Credits	6
Study Program	MSc Water *Science & Engineering*, compulsory elective module in the profile 'Environmental System Dynamics and Management' MSc *Applied Geosciences*
Instruction Language	German
Duration	1 semester
Module Frequency	Each winter semester
Learning Controls/Exams	Examination of other type: Written report and presentation on an exercise on groundwater modeling
Special Features of the Exam	None
Grade	Grade of the examination of other type
Requirements	None
Recommendations	Module 'Hydrogeology (AF801)' is strongly recommended.
Conditions	None
Restrictions	The courses in this module have limited capacity. Please register using ILIAS.
Learning Outcomes	- See German version

Courses	Title	Type	HPW	Semester		Lecturer
	Groundwater Modeling/ Grundwassermodellierung	L/T	2/2	W		T. Liesch
Content	- See German version					
Workload	Attendance time: 60 h Preparation/follow-up: 60 h Examination + exam preparation: 60 h					
Literature/ Learning Materials						

Karst and Isotopes/ Karst und Isotope

Module Code	PC841
Responsible Lecturer	**Prof. Dr. Nico Goldscheider**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Environmental System Dynamics and Management' MSc *Applied Geosciences*
Instruction Language	German
Duration	2 semesters, starting in winter semester
Module Frequency	Each winter semester
Learning Controls/Exams	Written exam, 120 min
Special Features of the Exam	None
Grade	Grade of the written exam
Requirements	None
Recommendations	Module 'Hydrogeology (AF801)' is strongly recommended.
Conditions	None
Learning Outcomes	- See German version

Courses	Title	Type	HPW	Semester		Lecturer
	Karst Hydrogeology/ Karsthydrogeologie	L/T	2	W		N. Goldscheider
	Field Trip Karst Hydrogeology/Exkursion zur Karsthydrogeologie	E	3 days		S	N. Goldscheider
	Isotope Methods in Hydrogeology/ Isotopenmethoden in der Hydrogeologie	L/T	2 days		S	T. Himmelsbach
Content	- See German version					
Workload	Attendance time: 60 h Preparation/follow-up: 70 h Examination + exam preparation: 50 h					
Literature/ Learning Materials	Ford, D., Williams, P. (2007): Karst Hydrogeology and Geomorphology. Wiley, 576 S. Goldscheider, N., Drew, D. (2007): Methods in Karst Hydrogeology. Taylor & Francis, London, 264 S. Kresic N (2013) Water in Karst. Management, Vulnerability, and Restoration. McGraw-Hill, New York, 708 p White, W.B. (1988): Geomorphology and Hydrology of Karst Terrains. Oxford University Press, New York, NY, 464 S. Internet: www.iah.org/karst					

Management of River and Wetland Ecosystems/ Management von Fluss- und Auenökosystemen

Module Code	PC986
Responsible Lecturer	**Prof. Dr. Florian Wittmann**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module in the profile 'Environmental System Dynamics and Management' MSc *Geoecology* MEd *Geography*
Instruction Language	German
Duration	2 semesters, starting in winter semester
Module Frequency	Each winter semester
Learning Controls/Exams	Partial examination 'Ecology of Rivers and Wetlands' (3 CP): Written exam, 90 min Partial examination 'Ecosystem Management' (3 CP): Examination of other type (presentation of 20 to 30 min)
Special Features of the Exam	None
Grade	Weighted average of the grades of the partial exams according to credit points
Requirements	None
Recommendations	None
Conditions	None
Learning Outcomes	- See German version

Courses	Title	Type	HPW	Semester		Lecturer
	Ecology of Rivers and Wetlands / Fluss- und Auenökologie	L	2	W		F. Wittmann
	Ecosystem Management/ Ökosystemmanagement	S	2		S	F. Wittmann C. Damm
Content	- See German version					
Workload	Attendance time: 60 h Preparation/follow-up: 60 h Examination + exam preparation: 60 h					
Literature/ Learning Materials						

2.7 Additional Supplementary Modules

Thermal Use of Groundwater

Module Code	SM879
Responsible Lecturer	**Prof. Dr. Philipp Blum**
Level	4
ECTS Credits	3
Study Program	MSc *Water Science & Engineering*, compulsory elective module as supplementary module within the profile studies
Instruction Language	English
Duration	1 Semester
Module Frequency	Each winter semester
Learning Controls/Exams	Oral exam, 30 min
Special Features of the Exam	None
Grade	Grade of the oral exam
Requirements	None
Recommendations	Knowledge of programming with Matlab. Otherwise, it is strongly recommended to participate in the course 'Introduction to Matlab (CC772)'.
Conditions	None
Learning Outcomes	Students get familiar with the topic 'Thermal Use of Groundwater' and will be able to integrate their knowledge in particular in an urban water energy nexus. They get knowledge about the fundamentals of thermal transport in groundwater and their application to shallow geothermal systems such as ground source and groundwater heat pump systems. Hence, analytical and numerical simulations will be performed using Excel and Matlab scripted codes. They will be able to perform their own simulations and will be able to design shallow geothermal systems in context of the water energy nexus.

Courses	Title	Teaching mode	Hours/ week	Semester		Lecturer
	Thermal Use of Groundwater	L/T	2	W		P. Blum
Content	The content of this module is mainly based on the textbook on 'Thermal Use of Shallow Groundwater' and is therefore structured as follows: - Fundamentals (theory of heat transport in the subsurface) - Analytical solutions for closed and open systems - Numerical solutions for shallow geothermal systems - Long-term operability and sustainability - Field methods such as thermal tracer tests and thermal response tests (TRT) - Case studies and applications Analytical simulations are performed using Excel and Matlab scripted codes. In addition, calibration and validation exercises are performed using existing field and monitoring data. Finally, the students are actively planning an own geothermal system from the application up to the long-term performance of such a system. Hence, a final planning report should be written.					
Workload	Attendance time: 30 h Preparation/follow-up: 30 h Examination + exam preparation: 30 h					
Literature/ Learning Materials	Stauffer, F., Bayer, P., Blum, P., Molina-Giraldo, N., Kinzelbach W. (2013): Thermal Use of Shallow Groundwater. 287 pages, CRC Press. Other documents such as recent publications are made available on ILIAS					

Earthwork and Embankment Dams/ Erdbau und Erddammbau

Module Code	SM961
Responsible Lecturer	**Prof. Dr.-Ing. Theodoros Triantafyllidis**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module as supplementary module within the profile studies
Instruction Language	German
Duration	2 semesters; starting in winter semester
Module Frequency	Each winter semester
Learning Controls/Exams	Oral exam, 40 min
Special Features of the Exam	None
Grade	Grade of the oral exam
Requirements	None
Recommendations	None
Conditions	Mutually exclusive with the modules *bauiM5P2-ERDGB* and *bauiM5S04-GWDAMM* from the MSc *Civil Engineering*
Learning Outcomes	- See German version

Courses	Title	Type	HPW	Semester		Lecturer
	Grundlagen des Erd- und Dammbaus	L/T	2	W		A. Bieberstein
	Erddammbau	L/T	2		S	A. Bieberstein
Content	- See German version					
Workload	Attendance time: 60 h Preparation/follow-up: 60 h Examination + exam preparation: 60 h					
Literature/ Learning Materials	- See German version					

Environmental Geotechnics/ Umweltgeotechnik

Module Code	SM962
Responsible Lecturer	**Prof. Dr.-Ing. Theodoros Triantafyllidis**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module as supplementary module within the profile studies MSc *Civil Engineering*
Instruction Language	German
Duration	1 semester
Module Frequency	Each winter semester
Learning Controls/Exams	- See German version
Special Features of the Exam	None
Grade	- See German version
Requirements	None
Recommendations	None
Conditions	None
Learning Outcomes	- See German version

Courses	Title	Type	HPW	Semester		Lecturer
	Übertagedeponien	L/T	2	W		A. Bieberstein
	Altlasten - Untersuchung, Bewertung und Sanierung	L	2	W		A. Bieberstein, T. Neumann, H. Würdemann, U. Mohrlok, S. Norra, M. Reinhard, H. Dörr
Content	- See German version					
Workload	Attendance time: 60 h Excursions: 10 h Preparation/follow-up: 50 h Examination + exam preparation: 60 h					
Literature/ Learning Materials	- See German version					

General Meteorology/ Allgemeine Meteorologie

Module Code	SM971
Responsible Lecturer	**Prof. Dr. Christoph Kottmeier**
Level	2
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module as supplementary module within the profile studies (BSc *Meteorology*)
Instruction Language	German
Duration	1 semester
Module Frequency	Each winter semester
Learning Controls/Exams	- See German version
Special Features of the Exam	None
Grade	The module is not graded (pass/fail).
Requirements	None
Recommendations	None
Conditions	None
Learning Outcomes	- See German version

Courses	Title	Type	HPW	Semester		Lecturer
	Allgemeine Meteorologie (4051011)	L	3	W		C. Kottmeier
	Übungen zur Allgemeinen Meteorologie (4051012)	T	2	W		C. Kottmeier, E. Hubel
Content	- See German version					
Workload	Attendance time: 75 h Preparation/follow-up: 105 h					
Literature/ Learning Materials						

Meteorological Hazards and Climate Change/ Meteorologische Naturgefahren und Klimawandel

Module Code	SM972
Responsible Lecturer	**Prof. Dr. Peter Knippertz**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module as supplementary module within the profile studies
Instruction Language	German/English
Duration	1 semester
Module Frequency	Each semester
Learning Controls/Exams	Partial exam ‘Meteorological Hazards’ (3 CP): Oral exam, 30 min Partial exam ‘Advanced Seminar IPCC progress report’ (3 CP): Examination of other type (presentation of about 30 min)
Special Features of the Exam	None
Grade	Weighted average of the grades of the partial exams according to credit points
Requirements	None
Recommendations	Basic knowledge of meteorology, for example module „Allgemeine Meteorologie (SM971)“, and basic knowledge on the climate system
Conditions	None
Learning Outcomes	Students are able to describe and critically discuss causes and effects of climate change. The can assess the potential of extreme events and their effects using climate and weather data or predictions, respectively, for different regions and seasons. Furthermore, they are able to professionally present and discuss scientific findings from the literature and their own work.

Courses	Title	Type	HPW	Semester		Lecturer
	Meteorologische Naturgefahren/ Meteorological Hazards	L	2		S	M. Kunz
	Hauptseminar IPCC Sachstands-bericht/Advanced Seminar IPCC Assessment Report	S	2	W		H. Fink, M. Höpfner
Content	**Meteorological Hazards:** Extreme events, extratropical and tropical cyclones, convection, thunderstorms, supercells, tornadoes, convective gusts, derechos, hail, extreme events and climate change **Advanced Seminar IPCC Assessment Report:** Causes of climate change, external and internal factors in the climate system, radiation effects and relevance of greenhouse gases, results from global climate models Systematic treatment on the basis of the current progress report of the Intergovernmental Panel on Climate Change: Structure of the IPCC process, background information on the development of the report, presentations on particular aspects, and discussion					
Workload	Attendance time: 60 h Preparation/follow-up including presentation: 90 h Examination + exam preparation: 30 h					
Literature/ Learning Materials						

Applied Meteorology: Turbulent Transport/ Angewandte Meteorologie: Turbulente Ausbreitung

Module Code	SM973
Responsible Lecturer	**Dr. Bernhard Vogel**
Level	4
ECTS Credits	6
Study Program	MSc *Water Science & Engineering*, compulsory elective module as supplementary module within the profile studies MSc *Meteorology*
Instruction Language	German
Duration	1 Semester
Module Frequency	Each summer semester
Examinations/Partial Deliveries	- See German version
Special Features of the Exam	None
Grade	- See German version
Requirements	None
Recommendations	Basic knowledge of meteorology, for example module „Allgemeine Meteorologie (SM971)“
Conditions	None
Learning Outcomes	- See German version

Courses	Title	Type	HPW	Semester		Lecturer
	Turbulente Ausbreitung (4052081)	L	2		S	H. Vogel, B. Vogel
	Übungen zu Turbulente Ausbreitung (4052082)	T	1		S	H. Vogel, B. Vogel
Content	- See German version					
Workload	Attendance time: 45 h Preparation/follow-up including exercises: 105 h Examination + exam preparation: 30 h					
Literature/ Learning Materials						

2.8 Study Project

Study Project

Module Code	SP111
Responsible Lecturer	**Prof. Dr. Markus Uhlmann (speaker of the study program)**
Level	5
ECTS Credits	15
Study Program	MSc *Water Science & Engineering*
Language	English or German. On agreement with the examiner(s), the 'Study Project' can also be written in other languages.
Duration	1 semester
Module Frequency	Each semester
Examinations/Partial Deliveries	Examination of other type: written report (about 30 pages) and final presentation (20 minutes)
Special Features of the Exam	None
Grade	Grade of the examination of other type
Requirements	None
Recommendations	The knowledge and technical and interdisciplinary skills needed to work on the selected topic and to prepare the 'Study Project' should have been acquired.
Conditions	None
Learning Outcomes	Students are able to work on an interdisciplinary, water-related project using scientific methods. They can, with guidance, plan, structure, prepare, conduct, and document a study. They are able to select appropriate methods for the solution of the given problem. Students are able to work self-organized and structured. They possess skills in the field of project management, teamwork and presentation, both orally and in writing.

Content	Conducting a water-related, interdisciplinary project work. This may be of a theoretical and/or experimental type. The focus is on the development of conclusions using scientific methods, project management and presentation of the results. The project can also be worked on in student teams. In this case, each student works on a particular aspect of an overall problem as part of a joint project. Students are invited to make suggestions for topics. It is possible to conduct the project in cooperation with external partners.
Workload	3 months (450 h)
Literature/ Learning Materials	

2.9 Master's Thesis

Master's Thesis

Module Code	MT199
Responsible Lecturer	**Prof. Dr. Markus Uhlmann (speaker of the study program)**
Level	5
ECTS Credits	30
Study Program	MSc *Water Science & Engineering*
Language	English or German; On request, the master's thesis can also be written in another language.
Duration	1 semester
Module Frequency	Each semester
Examinations/Partial Deliveries	Written report (master's thesis) and presentation
Special Features of the Exam	None
Grade	The overall grade results from the evaluations of the thesis and the final presentation.
Requirements	Students have successfully completed modules with a minimum of 42 ETCS credits.
Recommendations	The module 'Study Project' should be completed. The knowledge and technical and interdisciplinary skills needed to work on the selected topic and to prepare the thesis should have been acquired.
Conditions	None
Learning Outcomes	Students are able to independently develop and carry out a scientific work. To this end, they deal with the latest state of research and apply the knowledge and the methods acquired during the course of studies. They can discuss and evaluate the obtained results, and present them in writing as well as defend the work in a presentation.

Content	The master's thesis is an original scientific study, and includes the theoretical and/or the experimental work on a complex problem using scientific methods. Students may choose a subject area, which determines the topic of their thesis. Students are invited to make suggestions for topics. It is possible to conduct the project in cooperation with external partners, for example an external research institution or an institution from the professional background.
Workload	6 months (900 h)
Literature/ Learning materials	

3 Abbreviations

AF	Advanced Fundamentals
CC	Cross-Cutting Methods & Competencies
CP	Credit Points
E	English
E	Excursion
EoT	Examination of Other Type
ER	Examination Regulations
G	German
G/E	Documents: English/Teaching Language: German
HPW	Class Hours per Week
L	Lecture
LC	Learning Control
oE	Oral Examination
P	Practical Training
P	Profile Studies
P/SM	Profile Studies/Supplementary Modules
PA	Profile A
PB	Profile B
PC	Profile C
PD	Profile D
S	Seminar
S	Summer Semester
SP	Study Project
SP	Study Project
SPO	Studien- und Prüfungsordnung
T	Tutorial
uLC	Ungraded Learning Control
W	Winter Semester
wE	Written Examination

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