1.	**Higher Mathematics and Data Science**			
	Water Engineering Master (WEM)			**WEM1110**
2.	ECTS	**3 CP**	3. Workload	**90 h**
	Semester hours per week	**2 SWS**	Presence hours	**30 h**
	Module type	**Compulsory**	Self-study hours	**60 h**
4.	Exam type	**Written examination**	60 min	**WEM1110**
	Study achievements	**no**		
5.	Participation prerequisites			
6.	Frequency	**Winter semester**	7. Form of learning	
	Semester of studies	**1. Semester**	Lecture	**x**
	Length (semesters)	**1**	Excercise	**x**
	Teaching language	**English**	Practical training	
	Form of learning	**Presence**	Project work	
	Module abbreviation	**hmath**	Seminar	
	Responsible Lecturers	1. **Prof. Dr. rer. nat. C. Külls (kü)**	Excursion	
		2. **Prof. Dr.-Ing. habil. M. Oertel (oer)**		
8.	**Knowledge**	* Students will learn multivariate statistics for geo and water sciences, ordinary multiple regression techniques including hypothesis testing methods * Course participants will know multi-variate classification and multi-dimensional pattern recognition techniques for water sciences * Students will learn time series analysis for water science, anova and auto-correlation techniques, trend analyis, outlier identification and testing for stationarity and significant changes in mean, variance or other moments * Students will learn regionalization techniques, kriging, partial moments * Participants will learn differential equations in water science and engineering for flow systems: analytical and numerical solutions and integration		
9.	**Skills**	* Ability to define analyse complex multivariate data and identify stat. models * Students will acquire skills to apply learning techniques to multi-variate data in water sciences and use these models for predictions * Participants will be able to analyse time series, identify trends and non-stationarity, develop prediction techniques based anova techniques and filters * Students will acquire the skill to regionalize data based on statistical techniques and identify the uncertainty of the prediction * Students will be able to solve partial differential equations analytically or numerically and to apply optimization techniques for water systems		
10.	**Learning outcomes**	* Students can solve water science and water engineering problems with adequate statistical, analytical, and numerical tools * Students can characterise and analyse big data in water sciences (high-resolution time series and digital maps) applying time series analysis and regionalization techniques * Students can solve water flow, solute and mass transport equations in all compartments and all media (air-evaporation, soil-Richards equation, ground water - Laplace and river St. Venant equ. with analytical or numerical tools * Students can find optimal solutions for water distribution and fit analytical and numerical models and identify uncertainty, multi-finality and model fitness		
11.	**Literature**	* Papula (2014) Mathematik für Ingenieure und Naturwissenschaftler, Bd 1-3, Angewandte Aufgaben, Formelsammlung. Springer (5 volumes) * Kreyszig (2016) Engineering Mathematics. 10th edition, Wiley. 1112 p.		

1.	**Research Methods**				
	Water Engineering Master (WEM)				**WEM1120**
2.	ECTS Semester hours per week Module type	**3 CP** **2 SWS** **Compulsory**	3.	Workload Presence hours Self-study hours	**90 h** **30 h** **60 h**
4.	Exam type Study achievements	**Project** **yes (SL)**			**WEM1121** **WEM1122**
5.	Participation prerequisites				
6.	Frequency Semester of studies Length (semesters) Teaching language Form of learning Module abbreviation Responsible Lecturers	**Winter semester** **1. Semester** **1** **English** **Presence** **reme** 1. **Prof. Dr.-Ing. habil. M. Oertel (oer)** 2. **Prof. Dr. rer. nat. C. Külls (kü)**	7.	Form of learning Lecture Excercise Practical training Project work Seminar Excursion	 **x** **x** **x**
8.	**Knowledge**	* Research design and development of experimental aproaches * Software tools for reproducible research and programming * Scientific editing and redaction * Scientific graphs and visualization of data * Programming for data science and data analysis (e.g. MATLAB or Python) * Learning and deep learning algorithms for time series analysis * Artificial intelligence and pattern recognition for applied water science * Software for statistical analysis of big data * Scientific visualization and presentation techniques			
9.	**Skills**	* Students will learn to use modern software tools for reproducible analysis of data and automated reading, analysis of data streams * Students will learn to structure, write and redact / review scientific articles and text using adequate tools and methods for referencing (bilbiography), writing and reviewing * Students will learn an object oriented, structured programming language for scientific analysis * Students will be able to apply artificial analysis and learning tools to big data			
10.	**Learning outcomes**	* Students can process extensive, complex, multi-dimensional data * Students can write scientific articles for peer-reviewed journals and understand the peer redation and review process * Students can program data collection, data analysis and visualization algorithms for water science problems * Students understand and are able to write, modify and improve algorithms of water science models, e.g. rainfall-runoff, channel flow and groundwater flow * Students are able to apply AI-based algorithms for learning, optimization and data-based prediction			
11.	**Literature**	* Kreyszig (2016) Advanced Engineering Mathematics. John Wiley & Sons * Hastie, Tibshirani, Friedman (2018) The Elements of Statistical Learning. Springer * Raschka (2018) Python Machine Learning. Packt Ed. * Ebel, Bliefert, Russey (2004) The art of scientific writing. Wiley.			

1.	**Water Regulations**				
	Water Engineering Master (WEM)				**WEM1130**
2.	ECTS	**3 CP**	3.	Workload	**90 h**
	Semester hours per week	**2 SWS**		Presence hours	**30 h**
	Module type	**Compulsory**		Self-study hours	**60 h**
4.	Exam type	**Written examination**		60 min	**WEM1130**
	Study achievements				
5.	Participation prerequisites				
6.	Frequency	**Winter semester**	7.	Form of learning	
	Semester of studies	**1. Semester**		Lecture	**x**
	Length (semesters)	**1**		Excercise	
	Teaching language	**English**		Practical training	
	Form of learning	**Presence**		Project work	
	Module abbreviation	**ware**		Seminar	
	Responsible Lecturers	1. **Dr.-Ing. K. Wellbrock (wel)** 2. **Prof. Dr. rer. nat. C. Külls (kü)**		Excursion	
8.	**Knowledge**	Students will know the key aspects of * European Water Framework Directive (WFD) for water management * Groundwater regulations, Groundwater Directive and Nitrate Directive * Drinking water regulations based on WHO standards and recommendations * Sewage water regulations * Bathing water quality Directive * Flood Management Directive and the implications for urban planning * Environmental Impact Assessment standards * German soil protection law as a guideline (in the absence of a EU Directive)			
9.	**Skills**	Students are able * to apply for a permission under European water regulations * to assess water quality based on European regulations * to appply flood risk management regulations * to prepare applications for water abstraction and measures with impact on water resources			
10.	**Learning outcomes**	Students * are aware of relevant water laws and regulations in Europe * have written a water permit application * can assess water regulations during designing and operation of technical infrastructure related to water engineering			
11.	**Literature**	* Kingston (2017): European Environmental Law. Cambridge University Press, 2017. * Sands et al. (2018): Principles of International Environmental Law, Cambridge University Press, 2018. * McCaffrey, Stephen C. (2001). The Law of International Watercourses: Non-navigational uses. Oxford University Press. ISBN 978-0-19-825787-5. * Borchardt, D., et al. (2016): Integrated Water Resources Management: Concept, Springer			

1.	**Advanced Waste Water Treatment**			
	Water Engineering Master (WEM)			**WEM1140**
2.	ECTS	**3 CP**	3. Workload	**90 h**
	Semester hours per week	**2 SWS**	Presence hours	**30 h**
	Module type	**Compulsory**	Self-study hours	**60 h**
4.	Exam type	**Project**		**WEM1141**
	Study achievements	**yes (SL)**		**WEM1142**
5.	Participation prerequisites			
6.	Frequency	**Winter semester**	7. Form of learning	
	Semester of studies	**1. Semester**	Lecture	**x**
	Length (semesters)	**1**	Excercise	
	Teaching language	**English**	Practical training	**x**
	Form of learning	**Presence**	Project work	**x**
	Module abbreviation	**awwt**	Seminar	
	Responsible Lecturers	1. **Dr.-Ing. K. Wellbrock (wel)**	Excursion	
		2. **Prof. Dr.-Ing. M. Grottker (gro)**		
8.	**Knowledge**	Students will know * the theoretical background of occurence of micropollutants, microplastics and multiresistant bacteria in sewage * the relevant mechanisms of micropollutants`s removal, such as biodegradation, sorption or photolysis in sewage treatment plants and related models, * techniques of advanced waste water treatment (e.g. activated carbon, ozonisation, UV-treatment, membrane technology) for enhanced removal of micropollutants * to evaluate this methods in terms of cost efficency, energy demand, carbon footprint, removal rates etc. * the principles of online-monitoring for COD, nutrients and electrochemical parameters		
9.	**Skills**	Students will be able * to conduct laboratory analysis (of nutrients etc.) * to setup and maintain an online-monitoring system * to design sampling programmes in sewage systems and sewage treatment plants * to design treatment steps for enhanced micropollutant removal * to perform dynamic modelling of biological wastewater treatment (mainly activated sludge process) with respect to removal of micropollutants		
10.	**Learning outcomes**	Students can * aquire and analyse data of existing treatment plants * evaluate existing sewage treatment plants in terms of removal rates with respect to micropollutants and estimate the emissions * design new sewage treatment plants or treatment steps for enhanced micropollutant removal		
11.	**Literature**	* Gray (2017) Water Science and Technology: An Introduction, 4th edition, CRC/ Taylor & Francis * Butler et al. (2018, eds.) Urban Drainage, 4th edtion, CRC/ Taylor Francis * Metcalf & Eddy (2013) Wastewater Engineering – Treatment and Resource Recovery		

1. Urban Water Protection

Water Engineering Master (WEM) **WEM1150**

No.			No.		
2.	ECTS	**6 CP**	3.	Workload	**180 h**
	Semester hours per week	**4 SWS**		Presence hours	**60 h**
	Module type	**Compulsory**		Self-study hours	**120 h**
4.	Exam type	**Portfolio**			**WEM1150**
	Study achievements	(announcement in 1st or 2nd semester week)			
5.	Participation prerequisites				
6.	Frequency	**Winter semester**	7.	Form of learning	
	Semester of studies	**1. Semester**		Lecture	**x**
	Length (semesters)	**1**		Excercise	
	Teaching language	**English**		Practical training	
	Form of learning	**Presence**		Project work	**x**
	Module abbreviation	**uwp**		Seminar	
	Responsible Lecturers	1. **Prof. Dr.-Ing. M. Grottker (gro)**		Excursion	**x**
		2. **Dr.-Ing. K. Wellbrock (wel)**			

8. Knowledge

Students will know the most important aspects of
* Urban hydrology - introduction, objectives, methods
* Processes of urban hydrology - flow paths, sources and sinks of urban waters and loads, transport and storage, degradation and separation processes
* Hydrometry in urban water systems - measurement parameters, sensors, devices and transmission systems
* Emission and immission based concepts of urban water protection - development goals, urban water habitat, ecological sanitation, stormwater management
* Case study on urban water protection - identification/measurement of river catchment characteristics, modelling of water balance in urban catchment areas, hydrological proof, developing river protection measures

9. Skills

Students are able
* to identify the detailed background / interaction of subprocesses in urban hydrology
* to understand the interaction between drainage systems, treatment plants and urban waters
* to understanding and application of emission and immission based regulations including their strengths and weaknesses
* to use special knowledge and skills on urban hydrology - laboratory and field experiments on water quality (nutrients etc.), basic modelling of water balance in urban catchment areas

10. Learning outcomes

Students
* can analyse and interpret complex urban water systems
* can evaluate emission and immission based methods
* intensified their abilities in teamwork, laboratory and field experiments

11. Literature

* Butler, D.; et al. (2018) Urban drainage, CRC Press
* Gray, N. (2017) Water Science & Technology, CRC Press
* BKW M3/M7: Immissionsorient. Anfordg. an Misch- und Niederschlagswassereinleitungen
* ARW-1: Schleswig-Holstein regulations on water balance of urban catchments
* H. Lotus, Water Resources, Pollution and Management, ISBN-13: 9781632397614
* T.A. Larsen et al, Source Separation and Decentralization for Wastewater

1.	**Hydraulic Engineering**			
	Water Engineering Master (WEM)			**WEM1160**
2.	ECTS Semester hours per week Module type	**6 CP** **4 SWS** **Compulsory**	3. Workload Presence hours Self-study hours	**180 h** **60 h** **120 h**
4.	Exam type Study achievements	**Project** **yes (SL)**		**WEM1161** **WEM1162**
5.	Participation prerequisites			
6.	Frequency Semester of studies Length (semesters) Teaching language Form of learning Module abbreviation Responsible Lecturers	**Winter semester** **1. Semester** **1** **English** **Presence** **hyeng1** 1. **Prof. Dr.-Ing. habil. M. Oertel (oer)** 2. **Prof. Dr. rer. nat. C. Külls (kü)**	7. Form of learning Lecture Excercise Practical training Project work Seminar Excursion	 x x x
8.	**Knowledge**	* Basic knowledge of hydraulic terms, steady, unsteady, uniform, non-uniform, sub- and supercritical flow conditions * Hydromechanics in natural river systems * Hydraulic structure design for restoration of river systems; e.g. fish steps or weirs * Hydraulic laboratory techniques - Froude- und Reynoldsmodels, incl. scale effects - Measurement devices, e.g. ultrasonic and ADV probes * Hydrometry in surface water (e.g. ADCP) based on DIN EN ISO 748 * Comparision between experimental, in-situ and numerical results * Analysing software tools (e.g. MATLAB)		
9.	**Skills**	* Understanding of hydraulic processes and hydraulic structure design backgrounds * Designing fish steps and weirs for river restoration * Application of experimental models in hydraulic laboratories incl. correct choice of model scales and knowledge about expected scale effects * Usage of special measurement devices and data analysis software products * Application of surface water in-situ measurment techniques (hydrometry)		
10.	**Learning outcomes**	* Students are able to understand hydraulic processes in river systems * Students can design various hydraulic structures * Students will understand the complexity of experimental models and their scales * Students can identify scale effects and their influence on data analysis * Students are able to plan and analyse measurement campaings in laboratories and in-situ campaigns in the river environment		
11.	**Literature**	* Oertel, M., Scriptum Hydraulic Laboratory Techniques * USBR (1980) Hydraulic Laboratory Techniques, United States Bureau of Recl. * DIN EN ISO 748 * Morgenschweis, G. (2012) Hydrometrie, 2. Edition, Springer		

1.	**Simulation and Modeling I**				
	Water Engineering Master (WEM)				**WEM1170**
2.	ECTS	**6 CP**	3.	Workload	**180 h**
	Semester hours per week	**4 SWS**		Presence hours	**60 h**
	Module type	**Compulsory**		Self-study hours	**120 h**
4.	Exam type	**Project**			**WEM1171**
	Study achievements	**yes (SL)**			**WEM1172**
5.	Participation prerequisites				
6.	Frequency	**Winter semester**	7.	Form of learning	
	Semester of studies	**1. Semester**		Lecture	**x**
	Length (semesters)	**1**		Excercise	
	Teaching language	**English**		Practical training	
	Form of learning	**Presence**		Project work	**x**
	Module abbreviation	**sim1**		Seminar	
	Responsible Lecturers	1. **Prof. Dr. rer. nat. C. Külls (kü)**		Excursion	
		2. **Prof. Dr.-Ing. habil. M. Oertel (oer)**			
8.	**Knowledge**	* Basic knowledge of hydrogeological terms * Properties of aquifers, physical laws of motion and flow of groundwater * Water movement in the unsaturated (recharge) and saturated zones * Measurement of parameters of conductivity, porosity, storativity * Processes and methods to determine groundwater recharge * Pumping test analysis for unconfined and confined and multi-layer aquifers * Analytical groundwater modeling * Numerical groundwater modeling with ModFlow * Applications of groundwater hydrology for remediation and restoration of aquifers * Natural attenuation			
9.	**Skills**	* Delineate and define and design groundwater protection zones * Estimate groundwater recharge in porous, fractured and complex aquifers * Estimate or determine hydraulic conductivity, porosity and storativity * Apply analytical laws of groundwater flow to simplified 1D and 2D problems * Apply and use numerical groundwater models for 2D and 3D problems * Estimate model parameters and the uncertainty of model results * Carry out environmental impact analysis for groundwater related problems * Fit models for steady and non-steady flow conditions * Plan and verify and validate tracer tests * Use groundwater models for planning groundwater remediation measures			
10.	**Learning outcomes**	* Students can design groundwater protection zones in various environments * Students can assess groundwater vulnerability and map it * Students can design groundwater monitoring networks, install piezometers * Students are able to apply, modify and validate analytical models * Students are able to develop complex numerical groundwater models, including parameter estimation, model calibration, validation and application to non-steady problems * Students are able to apply groundwater models for remediation measures * Students can use groundwater models to estimate sustainable yields and environmental flows			
11.	**Literature**	* Fetter C.W. (2019) Applied Hydrogeology. Prentice Hall, 4th ed. * Fetter C.W. (2017) Contaminant Hydrogeology. Waveland Press.			

1.	**Geographic Information Systems (GIS)**				
	Water Engineering Master (WEM)				**WEM1210**
2.	ECTS Semester hours per week Module type	**6 CP** **4 SWS** **Compulsory**	3.	Workload Presence hours Self-study hours	**180 h** **60 h** **120 h**
4.	Exam type Study achievements	**Project**			**WEM1210**
5.	Participation prerequisites				
6.	Frequency Semester of studies Length (semesters) Teaching language Form of learning Module abbreviation Responsible Lecturers	**Summer semester** **2. Semester** **1** **English** **Presence** **gis** 1. **Prof. Dr. rer. nat. C. Külls (kü)** 2. **Prof. Dr.-Ing. habil. M. Oertel (oer)**	7.	Form of learning Lecture Excercise Practical training Project work Seminar Excursion	 **x** **x**
8.	**Knowledge**	* Geographical data * Field of GIS applications focusing on water engineering and hydrology * Basics in cartography * Introduction for GIS software products (e.g. QGIS, Open Source) * Sources, generation, analysis and presentation of geodata * Shapes, raster data, projections and their storage and manipulation			
9.	**Skills**	* Application of GIS software in water engineering * Delineation of watersheds using raster data * Interpolation of point data for estimating rainfall fields by kriging, inverse distances * Editing and analysis of vector networks (river systems), network properties * Raster calculation for distributed hydrological modeling * Water balance modeling with GIS tools * Presentation of maps for water management purposes * Flood mapping			
10.	**Learning outcomes**	* Acquisition of basic GIS knowledge * Students can link database systems to geographic data * Students are able to create a GIS database for water projects * Students can develop GIS based hydrological structures and analyse them * Students can carry out water balance modeling for IWRM with GIS tools			
11.	**Literature**	* De Lange, N. (2013) Geoinformatik, 3. Ed., Springer, Berlin, ISBN 978-3-642-34807-5 * Bill, R. (2010) Grundlagen der Geo-Informationssysteme, 5. Ed., Wichmann, Heidelberg * van der Kwast, H., Menke, K. (2019) QGIS for Hydrological Applications: Recipes for Catchment Hydrology and Water Management (Englisch).			

1.	**Applied Freshwater Ecology**			
	Water Engineering Master (WEM)			**WEM1220**
2.	ECTS Semester hours per week Module type	**6 CP** **4 SWS** **Compulsory**	3. Workload Presence hours Self-study hours	**180 h** **60 h** **120 h**
4.	Exam type Study achievements	**Portfolio** (announcement in 1st or 2nd semester week)		**WEM1220**
5.	Participation prerequisites			
6.	Frequency Semester of studies Length (semesters) Teaching language Form of learning Module abbreviation Responsible Lecturers	**Summer semester** **2. Semester** **1** **English** **Presence** **afe** 1. **Prof. Dr. N. Reintjes (rei)** 2. **Prof. Dr. C. Külls (kü)**	7. Form of learning Lecture Excercise Practical training Project work Seminar Excursion	 **x** **x**
8.	**Knowledge**	* Theory of freshwater ecology * Relevant physico-chemical parameters with focus on the autecology, population ecology and community ecology of the biota and on ecosystem ecology in flowing (rivers and streams) and standing waters (reservoirs, lakes) * Interaction of water bodies with anthropogenic use; a.o. (+) ecosystem services of freshwater ecosystems (+) legal framework for the use and protection of water bodies (+) assessment and monitoring of water quality (+) pollution with chemicals (+) eutrophication (+) biodiversity losses (+) neobiota (+) aquaculture		
9.	**Skills**	* Students comprehend the complexity of aquatic systems including their biota and their interaction with terrestrial, atmospheric, climatic and geochemical processes * Students realise the value of freshwater systems and their ecosystem services for humanity * Students know the framework and the instruments for the assessment of the quality of natural water bodies		
10.	**Learning outcomes**	* Students are able to develop interdisciplinary approaches for the assessment and control of impacts of anthropogenic activities on freshwater ecosystems		
11.	**Literature**	* Dodds, W. K. & M. R. Whiles (2019): Freshwater Ecology: Concepts and Applications of Limnology (Aquatic Ecology); Academic Press; ISBN 978-0128132555 * Aquatic Ecology: A Multidisciplinary Journal Relating to Processes and Structures at Different Organizational Levels, ISSN: 1386-2588, Springer. * Journal of Freshwater Ecology, Tayloer & Francis.		

1.	**Sustainable Urban Systems** **Water Engineering Master (WEM)**			**WEM1230**
2.	ECTS Semester hours per week Module type	**6 CP** **4 SWS** **Compulsory**	3. Workload Presence hours Self-study hours	**180 h** **60 h** **120 h**
4.	Exam type Study achievements	**Portfolio** (announcement in 1st or 2nd semester week)	90 min	**WEM1230**
5.	Participation prerequisites			
6.	Frequency Semester of studies Length (semesters) Teaching language Form of learning Module abbreviation Responsible Lecturers	**Summer semester** **2. Semester** **1** **English** **Presence** **sus** 1. **Prof. F. Schwartze (schw)** 2. **Prof. Dr.-Ing. M. Grottker (gro)**	7. Form of learning Lecture Excercise Practical training Project work Seminar Excursion	 x x x
8.	**Knowledge**	Students will know the forces and trends of global urbanisation processes and the economic, social and ecological consequences and challenges * Structures and forms of urban development in different regions * Types and processes of formal and informal settlements especially in fast growing cities * urban stormwater systems - runoff formation, concentration and transport; drainage, storage and treatment facilities and their dimensioning * concepts for water sensitive urban design; impacts of land use on water balance and pollution loads * protection against extreme storm events		
9.	**Skills**	Students are able * to understand and describe complex urban systems in diferent regions * to draft urban improvment programs and projects by using tools to analysis and evaluate urban areas and systems as well as methods of participation in urban decision making and community-based concept for urban upgrading and development * to understand the function and dimensioning of urban stormwater systems * to calculate the urban water balance and deduce measures for robust catchmant areas * to protect urban areas from extreme storm events		
10.	**Learning outcomes**	• Students understand the concept of sustainability in urban systems and are acquainted with related formal and informal planning policies, strategies and instruments and their implementation • Students have the ability to develop and design integrated planning solutions for water management in urban areas in different contextes and scales • Students are able to develop and apply solutions of integrated water management with a specific regard on water and climate related adaptation measures in urban areas		
11.	**Literature**	* Mostafavi, Mohsen et al. (Ed.) (2010) Ecological Urbanism. Lars Müller Publ., Baden * Pahl-Weber, Elke & Schwartze, Frank (Ed.) (2014) Space Planning and Design. Integrated Planning and Design Solutions for future Megacities, Jovis, Berlin * Sharma, Ashock et al (ed.) (2018) Approaches to Water Sensitive Urban Design - Potential, Design, Ecological Health, Economics, Policies and Community Perceptions, Elsevier		

1.	**Hydrological Engineering**			
	Water Engineering Master (WEM)			**WEM1240**
2.	ECTS Semester hours per week Module type	**6 CP** **4 SWS** **Compulsory**	3.	Workload **180 h** Presence hours **60 h** Self-study hours **120 h**
4.	Exam type Study achievements	**Project**		**WEM1240**
5.	Participation prerequisites			
6.	Frequency Semester of studies Length (semesters) Teaching language Form of learning Module abbreviation Responsible Lecturers	**Summer semester** **2. Semester** **1** **English** **Presence** **hyeng2** 1. **Prof. Dr. rer. nat. C. Külls (kü)** 2. **Prof. Dr.-Ing. habil. M. Oertel (oer)**	7.	Form of learning Lecture **x** Excercise **x** Practical training Project work Seminar Excursion
8.	**Knowledge**	* Hydrological processes: precipitation, evaporation, infiltration, percolation, discharge, runoff generation * Rainfall-runoff models for plots and micro, meso and macro scale basins * Analysis of hydrological extremes: droughts and floods * Hydrometry and development of monitoring networks * Hydrological data analyis: a) statistical, b) parametric and c) conceptual * Design of hydrological engineering approaches: artificial wetlands, flood retention, artificial recharge, natural attenuation, retention of water and solutes * Remediation schemes for surface and groundwater * Sustainable Water Management		
9.	**Skills**	* Students understand and can predict hydrological processes * Students can measure hydrological processes in the field * Students can analyse hydrological data (precipitation, runoff) * Students can apply and develop hydrological rainfall-runoff models * Students can plan and execute hydrological engineering designs e.g. managed aquifer recharge, schemes, meadow irrigation, artificial wetlands, flood retention, solute retention and remediation schemes * Students can assess the environmental impact of these schemes * Students know integrated water resources assessment and can define hydrological engineering measure to improve water management		
10.	**Learning outcomes**	* Students have the capacity to analyse a basin in terms of available water resources and can assess the sustainability of current water uses. * Students are able to design and plan measures that improve current water management conditions towards reaching sustainability and improving ecosystem services by applying hydrological engineering * Students can plan and design hydrological engineering solutions that integrate into the environment taking into account the environmental impact of these measures		
11.	**Literature**	* Maliva (2019) Anthropogenic Aquifer Recharge, Springer * Chicharro & Müller (2016) Ecosystem Services and River Basin Ecohydrology, Springer * Davie & Quinn (2019) Fundamentals of Hydrology, Routledge		

1. Simulation and Modeling II

Water Engineering Master (WEM) — **WEM1250**

2. ECTS	**6 CP**	3. Workload	**180 h**
Semester hours per week	**4 SWS**	Presence hours	**60 h**
Module type	**Compulsory**	Self-study hours	**120 h**
4. Exam type	**Project**		**WEM1251**
Study achievements	**yes (SL)**		**WEM1252**
5. Participation prerequisites			

		7. Form of learning	
6. Frequency	**Summer semester**	Lecture	x
Semester of studies	**2. Semester**	Excercise	
Length (semesters)	1	Practical training	
Teaching language	**English**	Project work	x
Form of learning	**Presence**	Seminar	
Module abbreviation	**sim2**	Excursion	
Responsible Lecturers	1. **Prof. Dr.-Ing. habil. M. Oertel (oer)** 2. **Prof. Dr. rer. nat. C. Külls (kü)**		

8. Knowledge

* Basic knowledge of hydraulic terms
* Properties of river systems, physical laws of motion and flow of surface water
* Numerical modeling in hydraulic engineering, e.g. flood simulation or hydraulic structure design (fish steps, weirs)
  - 1D models
  - 2D depth averaged models
  - 3D CFD models
* Parameter estimation
* Discretisation, calibration, validation
* Result analysis

9. Skills

* Deep understanding of hydraulic processes
* Apply and use numerical surface water models for 1D, 2D and 3D problems, to answer environmental questions
* Estimate model parameters and the uncertainty of model results
* Estimate and determine roughness influences for surface water flows
* Fit models for steady and non-steady flow conditions
* Calibrate models with available data sets
* Create rating curves and head related discharge coefficients via numerical models

10. Learning outcomes

* Students are able to develop complex numerical surface water models, including parameter estimation, model calibration, validation and application to non-steady problems
* Students can create flood maps and risk areas for river flood areas
* Students can design and analyze hydraulic structures via numerical models
* Students can analyze numerical model results concerning structure's efficiencies
* Students are able to apply, modify and validate analytical models

11. Literature

* Ferziger, J.H., Peric, M. (2002) Computational Methods for Fluid Dynamics. 3rd ed., Springer, Berlin Heidelberg New York
* Wesseling,P. (2001) Principles of Computational Fluid Dynamics, Springer Series in Computational Mathematics, Vol. 29

1.	**Master Thesis**			
	Water Engineering Master (WEM)			**WEM6000**
2.	ECTS	**27 CP**	3. Workload	**810 h**
	Semester hours per week	**0 SWS**	Presence hours	**0 h**
	Module type	**Compulsory**	Self-study hours	**810 h**
4.	Exam type	**Final thesis**	25 weeks	**WEM6000**
	Study achievements			
5.	Participation prerequisites			
6.	Frequency	**Summer and winter semester**	7. Form of learning	
	Semester of studies	**4. Semester**	Lecture	
	Length (semesters)	**25 weeks**	Excercise	
	Teaching language	**English**	Practical training	
	Form of learning	**Presence**	Project work	
	Module abbreviation		Seminar	
	Responsible Lecturers	1. **Prof. Dr. rer. nat. C. Külls (kü)** 2. **Prof. Dr.-Ing. habil. M. Oertel (oer)**	Excursion	
8.	**Knowledge**	Students know techniques of scientific writing * master structuring of a scientific report * know citation rules * preparation of high-level scientific graphs * sound description of scientific methodology and research design * discussion of data and evidence based conclusions		
9.	**Skills**	Students will develop and demonstrate the skill to * apply water engineering and scientific methods to a research question * follow and apply principles of scientific methodology * solve applied problems of water engineering		
10.	**Learning outcomes**	Students are able to prepare a major scientific report and work independently.		
11.	**Literature**	* Gastel B., Day, R. (2016) How to Write and Publish a Scientific Paper, 8th Edition, Greenwood; English, ISBN-10: 1440842809. * Alley M. (2018) The Craft of Scientific Writing. Springer; 4th ed. ISBN-10: 1441982876		

1.	**Master Colloquium**			
	Water Engineering Master (WEM)			**WEM8000**
2.	ECTS Semester hours per week Module type	**3 CP** **0 SWS** **Compulsory**	3. Workload Presence hours Self-study hours	**90 h** **0 h** **90 h**
4.	Exam type Study achievements	**Final oral colloquium**	45 min	**WEM8000**
5.	Participation prerequisites			
6.	Frequency Semester of studies Length (semesters) Teaching language Form of learning Module abbreviation Responsible Lecturers	**Summer and winter semester** **4. Semester** **45 min** **English** **Presence** 1. **Prof. Dr. rer. nat. C. Külls (kü)** 2. **Prof. Dr.-Ing. habil. M. Oertel (oer)**	7. Form of learning Lecture Excercise Practical training Project work Seminar Excursion	
8.	**Knowledge**	Students know * scientific presentation technqiues * free oral presentation of scientific data * discussion techniques for the defense of the presentation * communication techniques for scientific results		
9.	**Skills**	* Prepare high level scientific talks adapted to the audience * Synthesize and presents scientific findings adequately * Argue based on data and scientific results * Assess results and draw adequate conclusions		
10.	**Learning outcomes**	Students can * prepare abstracts, executive summaries * present their findings in a professional manner * talk to the audience with optimal presentation techniques, use of different media and good oral communication		
11.	**Literature**	* Anderson C. (2017) TED Talks: The Official TED Guide to Public Speaking. ISBN-13: 978-1328710284 (in combination with TED Talk playlist) * Alley M. (2011) The Craft of Scientific Presentations: Critical Steps to Succeed and Critical Errors to Avoid (Englisch). ISBN-13: 978-1441982780		