COURSE UNIT (MODULE) DESCRIPTION

Course unit (module) title	Code
Groundwater modeling	**HGFM711**

Lecturer(s)	Department(s) where the course unit (module) is delivered
Coordinator: Marius Gregorauskas **Other(s):**	Faculty of Chemistry and Geosciences, Vilnius University Institute of Geosciences Department of Hydrogeology and Engineering Geology

Study cycle	Type of the course unit (module)
Second	Compulsory

Mode of delivery	Period when the course unit (module) is delivered	Language(s) of instruction
Face-to-face and distance learning	2nd semester	Lithuanian / English

Requirements for students	
Prerequisites: Hydrogeology, Hydrogeodynamics, Hydrogeochemistry, Higher mathematics	**Additional requirements (if any):**

Course (module) volume in credits	Total student's workload	Contact hours	Self-study hours
5	133	64	69

Purpose of the course unit (module): programme competences to be developed

To develop: ability to present research findings and decisions in the field of hydrogeology, hydraulics, mathematics and environment protection; ability of independent analytical thinking concerning problems of groundwater resources and their quality formation; ability to increase knowledge, to search for new or missing information; ability to apply the knowledge and understanding in practice; ability to understand and explain principles of interaction between various elements of geoenvironment and their balance.

Learning outcomes of the course unit (module)	Teaching and learning methods	Assessment methods
Will be able to analyze and systemize information.	Active lectures, problem-oriented teaching, exercises, discussions	Examination of theoretical and practical sections
Will master theoretical background of 3D groundwater flow and mass-transport, applied in mathematical modeling of these processes.	Active lectures, problem-oriented teaching, exercises, discussions	
Will master methodology of 3D groundwater flow and mass-transport modeling.	Active lectures, problem-oriented teaching, exercises, discussions	
Will be able to apply algorithms of modeling of hydrogeological processes and to use special programme codes	Active lectures, problem-oriented teaching, exercises, discussions	
Will be able to create 3D mathematical models of groundwater flow and pollution transport for various purposes.	Modeling of situations, analysis of results, exercises, discussions	
Will be able to make project-based decisions and conclusions	Active lectures, problem-oriented teaching, exercises, discussions	

Will be able to independently increase knowledge and to use up-to-date scientific achievements	Finding and reading of special literature and scientific papers	

Content: breakdown of the topics	Contact hours							Self-study work: time and assignments	
	Lectures	Tutorials	Seminars	Exercises	Laboratory work	Internship/work placement	**Contact hours**	**Self-study hours**	**Assignments**
1. Introduction. Importance of modeling of natural processes. Concept of mathematical model, types of models in hydrogeology. Main tasks of mathematical modelling, its advantages and limitations, practical examples.	2						**2**	**2**	Reading of special literature
2. Theoretical background of 3D modeling of groundwater flow and mass-transport. Main differential equations of groundwater flow and mass-transport in mathematical models. Finite difference and finite element methods. Iteration processes. Initial and boundary conditions, their types. Principles of discretization in space and time. Processes of advection, dispersion, sorbtion, decay etc. in mathematical models. Method of characteristics in mass-transport models. Particle tracking.	12						**12**	**9**	Reading of special literature
3. Methodology. Steps of modelling procedure. Conceptual model. Schematization of hydrogeological conditions. Formation of model grid, applying of initial and boundary conditions. Parameters needed for flow and transport models, their values. Model calibration and verification. Inverse modelling. Sensitivity analysis. Analysis of uncertainties. Prediction and optimization. Exercises and self-study tasks: creation of model calibration curves, evaluation of model error and statistical parameters of its calibration, inverse modeling and evaluation of hydrogeological parameters, evaluation of model sensitivity and uncertainty.	12			8			**20**	**22**	Reading of special literature Exercises and self-study tasks
4. Computer programs MODFLOW-2000, MODFLOW-2005, MT3DMS, MODPATH5.0, user interface GROUNDWATER VISTAS 6.0 (student version). Their purpose, structure, possibilities. Exercises and self-study tasks: studying of programme codes.	6			6			**12**	**15**	Reading of special literature Studying of programme codes
5. Practical compilation of flow and transport models in groundwater. Compilation of models for analysis of flow and transport processes, formation of resources and safe yield, prediction of groundwater quality, catchment and protection areas of wellfields, evaluation of water balance, etc. Exercises and self-study tasks: schematization of hydrogeological conditions, creation of model grid; modeling of steady-state and transient groundwater	-			18			**18**	**21**	Exercises and self-study tasks

flow and mass-transport in multi-layered systems; particle tracking, assesment of catchment and sanitary protection areas; evaulation of groundwater balance and sources of resources formation									
Total	**32**			**32**			**64**	**69**	

Assessment strategy	**Weight, %**	**Deadline**	**Assessment criteria**
Exam (test) of theoretical and practical sections	100	May	Test of theoretical section consists of 10 questions. Test of practical section consists of 10 exercises. Assessment criteria: **10 (excellent):** Excellent knowledge and abilities. 10 correct answers / exercises. **9 (very well):** Nice knowledge and abilities. 8-9 correct answers / exercises. **8 (well):** Good knowledge and abilities. 7 correct answers / exercises. **7 (moderately):** Moderate knowledge and abilities, inessential errors occure. 6 correct answers / exercises. **6 (satisfactorily):** Knowledge and abilities are worse than moderate, essential errors occure. 5 correct answers / exercises. **5 (weakly):** Knowledge and abilities satisfy only minimal requirements. 3-4 correct answers / exercises. **4 (unsatisfactorily):** Knowledge and abilities unsatisfy minimal requirements. 1-2 correct answers / exercises. Final assessment = (Assessment of theoretical section)*0.4 + (Assessment of practical section)*0,6

Author	**Year of publication**	**Title**	**Issue of a periodical or volume of a publication**	**Publishing place and house or web link**
Compulsory reading				
Anderson M.P., Woessner W.W.	1992	Applied Groundwater Modeling: Simulation of Flow and Advective Transport. 381 p.	-	New York, Academic Press Inc.
Bear J., Cheng A.H.-D.	2010	Modeling groundwater Flow and Contaminant Transport. 834 p.	-	Springer
Harbaugh A.W. et. al.	2000	MODFLOW-2000. The U.S. Geological Survey Modular Ground-Water Model - User Guide to Modularization Concepts and the Ground-Water Flow Process. 121 p.	-	Reston, U.S. Geological Survey http://www.usgs.gov/pubprod/
Harbaugh A.W.	2005	MODFLOW-2005.The U.S. Geological Survey Modular Ground-Water Model—the Ground-Water Flow Process. 253 p.	-	Reston, U.S. Geological Survey http://www.usgs.gov/pubprod/
Zheng C. , Wang P.P.	1999	MT3DMS: A Modular Three-Dimensional Multispecies Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems. 220 p.	-	Tuscaloosa, University of Alabama. http://hydro.geo.ua.edu/mt3d
Pollock D.W.	1994	User's Guide for	-	Reston, U.S. Geological

		MODPATH/MODPATH-PLOT, Version 3: A particle tracking post-processing package for MODFLOW, the U. S. Geological Survey finite-difference ground-water flow model. 249 p.		Survey http://www.usgs.gov/pubprod/
Optional reading				
Rumbaugh J., Rumbaugh D.	2010	Groundwater Vistas version 6. Guide to Using. 213 p.	-	Reinholds, Environmental Simulations Inc. www.groundwatermodels.com
Diersch H.-J.G.	2009	FEFLOW. Finite Element Subsurface Flow and Transport Simulation System. Reference manual. 292 p.	-	Berlin, DHI-WASY GmbH. http://www.feflow.info/