POSTGRADUATE PROGRAMMES IN ENVIRONMENTAL AND WATER ENGINEERING

MASTER OF ENGINEERING IN ENVIRONMENTAL AND WATER ENGINEERING

Department of Civil Engineering
Faculty of Engineering
University of Peradeniya

Course Structure

Course code	Title	Compulsory/ Optional	Credits
CE 6101	Research Methods in Civil Engineering	Optional	2
CE 6201	Environmental Hydraulics	Compulsory	3
CE 6202	Advanced Hydrology	Compulsory	3
CE 6203	Software Application in Water and Environmental Engineering	Compulsory	3
CE 6204	Wastewater Treatment and Reuse	Compulsory	2
CE 6205	Water Resources Project Planning	Compulsory	3
CE 6206	Water Supply Engineering	Compulsory	2
CE 6207	Climate Change Impacts and Adaptation in Water Sector	Optional	2
CE 6208	Coastal Engineering and Coastal Zone Management	Optional	2
CE 6209	Environmental Technology	Compulsory	2
CE 6210	Geographic Information Systems and Remote Sensing in Water Resources	Optional	2
CE 6211	Groundwater Hydrology	Optional	2
CE 6212	Hydraulic Structures	Optional	2
CE 6213	Industrial Waste Management	Optional	2
CE 6214	Integrated Water Resources Management	Optional	2
CE 6215	Irrigation and Drainage Engineering	Optional	2
CE 6216	Public Health Engineering	Optional	2
CE 6217	Solid Waste Management	Optional	2
CE 6103	**Advanced Study**	**Compulsory**	**5**

Number of credits from compulsory courses: 18
Number of credits from optional courses: 7
Number of credits from advanced study: 5
Total number of credits: 30

Course Code	**: CE 6101**
Course Title	**: Research Methods in Civil Engineering**
No. of Credits	**: 2**
Pre-requisites	**: -**
Compulsory/Optional	**: Optional**

Aim(s): To give the skills needed to plan and conduct a research study in order to create new knowledge in the field of Civil Engineering and related disciplines.

Intended Learning Outcomes:

On successful completion of the course, the student should be able to;

1. Describe the scientific research methods and how this applies to graduate research studies
2. Prepare a literature review on a topic relevant to their area of concentration by critically reviewing published papers
3. Analyse the collected data and identify the appropriate methods for displaying the data.
4. Prepare an extended abstract and present the research findings in an oral/poster format.

Time Allocation (Hours)	Lectures: 18 Tutorials: 02 Practicals: Assignments: 20 Independent learning: 60 (Notional hours=100)

Course Content/Course Description:

Fundamentals of Research:

Definition and Objectives of Research; Qualitative vs Quantitative Research; The Scientific Research Process; Identification, selection, and formulation of research problems; Characteristics of good research problems; Review of literature

Data Collection, Analysis and Presentation:

Methods and techniques of data collection; Design of Experiments; Sampling and sampling designs; Statistical modelling and analysis including introduction to statistical package; Probability Distributions; Multivariate methods; Concepts of correlation and regression, error analysis; Effective presentation of information using Tables, illustrations, graphs, etc.

Scientific writing and presentation:

Essential components of abstract, introduction, literature review, materials and methods, results, discussion, and conclusions; Formatting of contents; Methods of referencing and the use of referencing tools, Preparing and presenting a technical presentation.

Recommended Texts

Fellows R.F., Liu A.M.M., (2015). "Research Methods for Construction", 4th edition, Wiley Blackwell.

Thiel D.V, (2014)."Research Methods for Engineers", 1st edition, Cambridge university press.

Wayne C., Booth G.G.C., Joseph M.W., (2008). "The Craft of Research", 3rd Edition University of Chicago Press.

Willie T., (2017). Research Methods: A Practical Guide for Students and Researchers, World Scientific.

Assessment		Percentage Marks
In-Course	Assignments/Course work	100
End of Semester Examinations		-

Course Code	**: CE 6201**
Course Title	**: Environmental Hydraulics**
No. of Credits	**: 3**
Pre-requisites	**: None**
Compulsory/Optional	**: Compulsory**

Aim(s): To impart basic knowledge for analyzing pollution transport to assess, protect and manage surface water environments.

Intended Learning Outcomes:

On successful completion of the course, the student should be able to,

1. Quantitatively analyze transport and mixing of pollutants in surface water bodies by using concepts of fluid mechanics, hydraulics, and transport and mixing processes.
2. Apply suitable computational models to analyse the impacts of environmental pollution.
3. Select safe wastewater disposal techniques for disposal of wastewater into natural water bodies considering their pollutant assimilative capacities by application of water quality modelling tool.

Time Allocation (Hours)	Lectures:30 Tutorials:03 Practical: 20 Assignments:04 Independent learning: 93 (Notional hours = 150)

Course content/Course Description:

Fluid mechanics for environmental hydraulics:

Governing equations of fluid flow, Applications to pipe flows and free surface flows

Transport and mixing in fluids:

Mixing and transport processes, Fate & transport of pollutants, Wastewater disposal systems

Environmental modelling:

Hydrodynamic modelling, Pollutant transport and water quality modelling, Multi-dimensional and spatially averaged modelling, Modelling of aquatic systems, Application of water quality models

Recommended Texts

Ioannis Tsanis Jian Wu Huihua Shen CaterinaValeo, (2006), "Environmental Hydraulics-Hydrodynamic and Pollutant Transport Models of Lakes and Coastal Waters", ISBN: 9780444527127, Elsevier Science.

Chanson H., (2017). "Environmental Hydraulics for Open Channel Flows", ISBN: 978-0-7506-6165-2., Elsevier B.V.

Chapra S.C., (1997)."Surface Water Quality Modeling", McGraw-Hill, NY.

Chow V.T., *Maidment* D.R.,*Mays* L.W., (1998). "*Applied Hydrology*", McGraw- Hill, NY.

Singh V.P., Hager W.H., (1996). "Environmental Hydraulics", Kluwer academic publishers, The Netherlands.

Tchobanoglous G., Schroeder E.D., (1984)."Water Quality: Characteristics, Modeling, Modification", Addison-Wesley, Massachusetts.

Assessment		**Percentage Marks**
In-course	Assignment/ Course work	50
	Mid Semester Examination	-
End of Semester Examinations		50

Course Code	**: CE 6202**
Course Title	**: Advanced Hydrology**
No. of Credits	**: 3**
Pre-requisites	**: None**
Compulsory/Optional	**: Compulsory**

Aim(s): To equip the students with essential theoretical and design concepts in advance engineering hydrology.

Intended Learning Outcomes:

On successful completion of the course, the student should be able to,

1. Describe hydrologic processes and their importance in civil engineering applications.
2. Perform quality control of data, analyse and classify types of hydrological time series.
3. Perform frequency analysis of extreme values of precipitation and stream flows.
4. Compute design flows and hydrological extremes to carryout related designs.

Time Allocation (Hours)	Lectures: 34 Tutorials: 05 Practical: Assignments:12 Independent learning: 99 (Notional hours = 150)

Course content/Course Description:

Hydrological processes:

Physical principles governing hydrological processes, rainfall-runoff relationship (Conceptual and Physics-based types), Instantaneous Unit Hydrograph (IUH), Synthetic Unit Hydrograph (Clark Method, SCS Method), Impact of Climate Change and Land-use Changes, Depth-Area-Duration relationship

Hydrologic statistics:

Probability concepts, Probability density functions and Cumulative distribution functions, Hydrologic data handling, Fitting probability distributions Testing the goodness of fit

Frequency analysis:

Extreme value distributions and probability plotting, Frequency factors, Confidence limits, IDF Relationships

Hydrologic designs:

Risk, Design criteria, Derivation of design storms and design flows, Storm sewer design, Drainage design

Recommended Texts

Chow V.T., Maidment D.R., Mays L.W., (1988). "Applied Hydrology", McGraw-Hill.
Hann, C.T., (2002). "Statistical Methods in Hydrology", 2nd Edition, Wiley-Blackwell.
LinsleyJr.R.K. Kohler M.A., PaulhusJ.L., (1975). "Applied Hydrology", McGraw-Hill, New York.

Assessment		**Percentage Marks**
In-course	Assignment/ Course work	40
	Mid Semester Examination	-
End of Semester Examinations		60

Course Code	**: CE 6203**
Course Title	**: Software Applications in Water and Environmental Engineering**
No. of Credits	**: 3**
Pre-requisites	**: None**
Compulsory/Optional	**: Compulsory**

Aim(s): To equip students with knowledge and skills to use software related to water and environmental engineering.

Intended Learning Outcomes:

On successful completion of the course, the student should be able to;

1. Simulate basin hydrologic processes.
2. Simulate steady and unsteady river flows and conduct water quality modelling in surface water bodies.
3. Use computational tools to water resource project planning.
4. Design and simulate water supply, storm water and sewer network systems.
5. Simulate wastewater treatment unit processes.

Time Allocation (Hours)	Lectures:09 Tutorials: Practical: 32 Assignments:40 Independent learning: 69 (Notional hours=150)

Course content/Course Description:

Software packages related to:

Hydrology (eg.HEC-HMS); Hydraulics (eg.HEC-RAS/ FLO2D);
Irrigation engineering (eg. Cropwat /WEAP);Water supply and sewer networks (eg. WaterCAD/ SewerGems); Storm water drainage (eg.SWMM); Wastewater treatment plant design (eg.STOAT); Water quality modelling (eg.WASP)

Recommended Texts

Chadwick A., Morfett J., Borthwick M., (2013). "Hydraulics in Civil and Environmental Engineering", CRC press, 5th Edition.
McCuen R.H., (2016). "Hydrologic Analysis and Design", Pearson Education, 4thEdition.
Stephenson D., (2000). "Pipeline Design for Water Engineers", Volume 6, Elsevier Science, 1st Edition.
The catalogues of relevant software.

Assessment		**Percentage Marks**
In-course	Assignment/ Course work	100
End of Semester Examinations		-

Course Code	**: CE 6204**
Course Title	**: Wastewater Treatment and Reuse**
No. of Credits	**: 2**
Pre-requisites	**: None**
Compulsory/Optional	**: Compulsory**

Aim(s): To provide detailed knowledge of the current practices in wastewater treatment, with specific reference to reuse technologies, emerging wastewater treatment processes and environmental sustainability.

Intended Learning Outcomes:

On successful completion of the course, the student should be able to;

1. Select and use wastewater treatment processes leading to rational design of overall systems.
2. Define the quality parameters typically used to characterize wastewater and review treatment requirement of wastewater and reuse.
3. Design advanced processes in aerobic treatment, anaerobic treatment and nutrient removal.
4. Compare and apply emerging technologies for advanced wastewater treatment and reuse.
5. Design sludge treatment and disposal systems.

Time Allocation (Hours)	Lectures: 21 Tutorials:01 Practical: Assignments: 16 Independent learning: 62 (Notional hours=100)

Course Content/Course Description:

Introduction to wastewater treatment:

Quantity and quality, Characterization, Status, Trends and Needs for wastewater treatment and Reuse

Wastewater management systems :

Decentralized Vs centralized systems, Collection and transport

Wastewater treatment plant planning and design:

Volume, Design period, Demand calculation, Biological systems, (Conventional, on-site and high-efficiency/high rate), Introduction to Chemical processes (coagulation, oxidation etc), Residuals management

Wastewater reuse options:

Standards, Treatment options and application, Tertiary treatment options

Recommended Texts

Crittenden J.C., Trussell R.R., Hand D.W., Howe K.J., (2012).“MWH's Water Treatment: Principles and Design”,George Tchobanoglous Publisher: Wiley, 3rd Edition.

Eddy M., Asano T., Burton F.L., Leverenz H.L., Tsuchihashi R., Tchobanoglous G., (2006). “Water Reuse: Issues, Technologies, and Applications”, McGraw-Hill-New York.

Eddy M., Tchobanoglous G., Stensel H.D., Tsuchihashi R., (2013).“Wastewater Engineering: Treatment and Resource Recovery”, Franklin Burton Publisher: McGraw-Hill Education, 5th Edition.

Assessment		**Percentage Marks**
In-Course	Assignment/ Course work	40
End of Semester Examinations		60

Course Code	**: CE 6205**
Course Title	**: Water Resources Project Planning**
No. of Credits	**: 3**
Pre-requisites	**: None**
Compulsory/Optional	**: Compulsory**

Aim(s): To provide detailed knowledge for management and planning of water resources development projects.

Intended Learning Outcomes:

On successful completion of the course, the student should be able to;

1. Carryout feasibility studies for complex water resources projects.
2. Use system analysis and economic analysis techniques in planning and management of water resources development projects.
3. Prepare schedules for the implementation of water resource projects.
4. Appraise water law and policy, and discuss how it influences regional and national decision making on water resource use.

Time Allocation (Hours)	Lectures: 34 Tutorials:03 Practical: Assignments:16 Independent learning: 97 (Notional hours=150)

Course content/Course Description:

Water resources systems analysis and modelling:

General concepts of systems analysis, planning, designing and operation of water resources systems, Application of simulation, optimization and multi-criteria decision analysis models

Multipurpose river basin planning:

Inter-basin and inter-provincial water resources planning and management, Shared water resources and conflict management

Water policy and governance:

Water law and policy, Water rights, Institutional aspects, Water allocation laws

Economic analysis and project financing:

Economic and financial evaluations, Financial models, benefit cost analysis, risk and uncertainty, multipurpose development and cost allocations

Project planning:

Feasibility studies, Planning techniques and project scheduling, Environmental and social aspects, Environmental audit, Project monitoring and post project evaluation, Commissioning and follow-up action.

Recommended Texts

Katko T., Juuti P.S., Schwartz K., (2013). "Water Services Management and Governance, Governance and Management for Sustainable Water Systems Series", IWA publishing, London.

Loucks D.P.,Beek E.V.,(2005)."Water Resources Systems Planning and Management: An Introduction to Methods, Models and Applications", UNESCO, Paris.

Taylor J., (2007)."Project Scheduling and Cost Control: Planning, Monitoring and Controlling - Planning Monitoring and Controlling the Baseline", J. Ross Publishing.

Vedula S., Mujumdar P.P., (2005). "Water Resources Systems Modelling Techniques and Analysis", Tata-McGraw Hill, New Delhi.

Assessment		**Percentage Marks**
In-course	Assignment/ Course work	40
	Mid Semester Examination	-
End of Semester Examinations		60

Course Code	**: CE 6206**
Course Title	**: Water Supply Engineering**
No. of Credits	**: 2**
Pre-requisites	**: None**
Compulsory/Optional	**: Compulsory**

Aim(s): To provide in-depth knowledge and skills for design and manage drinking water supply schemes.

Intended Learning Outcomes:

On successful completion of the course, the student should be able to;

1. Identify the importance of water quality and standards in drinking water supply.
2. Design a conventional drinking water treatment plant associated with distribution network.
3. Analyse and propose appropriate advanced water treatment methods to treat source water from non-conventional sources and under special scenarios.
4. Appraise and solve major operational issues arise at a drinking water treatment plant.

Time Allocation (Hours)	Lectures: 24 Tutorials: 01 Practical: Assignments: 10 Independent learning: 65 (Notional hours=100)

Course content/Course Description:

Water quality parameters and standards:

Source water quality and safety, Drinking water standards

Conventional drinking water treatment :

Unit processes, Treatment mechanisms, Troubleshooting at the drinking water treatment plant

Design of water treatment unit processes:

Design of the conventional unit processes, Design of the advanced unit processes (plate/tube settlers, filter under drain systems etc.), Selection of pumps and internal plumbing systems, Wash water collection systems

Distribution networks:

Design of pipe networks (Storage reservoirs, Break pressure tanks, Pipes and Valves), Online measuring techniques, Non-revenue water (NRW) management systems.

Advanced water treatment processes:

Membrane technology, Desalination, Water softening, Precipitation methods, Adsorption, Ion exchange, UV irradiation

Recommended Texts

American Water Works Association, American Society of Civil Engineers, (2012). "Water Treatment Plant Design", McGraw-Hill.

Punmia B.C., Jain A., Jain A., (1995). "Water Supply Engineering", Laxmi Publications, New Delhi.

Twort A.C., Ratnayaka D.D., Brandt M.J., (2000). "Water Supply", 5th Edition, IWA publishing, London.

Assessment		**Percentage Marks**
In-course	Assignment/ Course work	40
End of Semester Examinations		60

Course Code	**: CE 6207**
Course Title	**: Climate Change Impacts and Adaptation in Water Sector**
No. of Credits	**: 2**
Pre-requisites	**: None**
Compulsory/Optional	**: Optional**

Aim(s): To provide knowledge on climate change impacts and adaptation techniques in water sector.

Intended Learning Outcomes:

On successful completion of the course, the student should be able to;

1. Explain climate change referred to science of climate system and drivers.
2. Describe the techniques available for downscaling of GCM predictions for basin scales.
3. Explain the anticipated impacts and propose climate change adaptation techniques with special reference to water resources management.

Time Allocation (Hours)	Lectures: 25 Tutorials: 02 Practical: Assignments:06 Independent learning: 67 (Notional hours=100)

Course content/Course Description:

Science of climate change:

Climate system, Drivers of climate change, Climate modelling and climate change projections, GCMs

Impacts of climate change:

Impacts on hydrologic cycle, Impacts on regional climate and water resources, Impacts on water infrastructure, agriculture, food security, health and other sectors

Adaptation for resilience:

Exposure, vulnerability and risk of climate change, Regional and local adaptations in water sector, Resilience and traditional systems, Governance and policy framework

Climate projection downscaling:

Statistical downscaling, Dynamic downscaling, Applications in designs of hydraulic structures and water management

Recommended Texts

Fung C.F., Lopez A., New M., (2016). "Modelling the Impact of Climate Change on Water Resources", Wiley-Blackwell.

Shrestha S., Babel M.S., Pandey V.P., (2014). "Climate Change and Water Resource", CRC Press.

Turral H., Burke J., Faurès J.M., (2011). "Climate Change, Water and Food Security", Food and Agriculture Organization of the United Nations, Italy.

Assessment		**Percentage Marks**
In-course	Assignment/ Course work	40
	Mid Semester Examination	-
End of Semester Examinations		60

Course Code	**: CE 6208**
Course Title	**: Coastal Engineering and Coastal Zone Management**
No. of Credits	**: 2**
Pre-requisites	**: None**
Compulsory/Optional	**: Optional**

Aim(s): To provide an in-depth analysis of the nearshore wave, hydrodynamic and morphodynamic processes and to address problems and issues in the coastal zone including the environmental effects of coastal interventions.

Intended Learning Outcomes:

On successful completion of the course, the student should be able to;

1. Analyse wave measurements and apply higher-order wave theories.
2. Analyse nearshore hydrodynamic and morphodynamic processes.
3. Develop a basic mathematical model related to coastal morphodynamics.
4. Plan and devise appropriate actions and responses in managing the problems and issues in the coastal zone.

Time Allocation (Hours)	Lectures: 26 Tutorials:02 Practical: Assignments:04 Independent learning: 68 (Notional hours=100)

Course content/Course Description:

Wave Mechanics:

Wave measurements, Analysis and non-linear wave theories

Coastal Processes:

Nearshore wave, Hydrodynamic and sediment transport processes;
Physical modeling of coastal processes, Mathematical modeling

Coastal Zone Management:

Coastal environment and landforms. Problems and issues in the coastal zone, Coastal interventions- hard and soft structures, Coastal hazards, Integrated Coastal Zone Management with particular reference to Sri Lanka.

Recommended Texts

Dean R.G.,Dalrymple R.A., (2004). "Coastal Processes with Engineering Applications", 1st edition, UK: Cambridge University Press.

French P.W., (2002). "Coastal Defences: Processes, Problems and Solutions", 1st edition, UK: Routledge.

Kamphuis J.W., (2010). "Introduction to Coastal Engineering and Management", 1st edition, Singapore: World Scientific.

Sorensen R.M., (2006). "Basic Coastal Engineering", 3rd edition, USA: Springer US.

Wijetunge J.J., (2013)."An Introduction to Coastal Engineering: Processes, Theory, Hazards and Design Practice", 1st edition, Colombo: Godage Publishers.

Assessment		**Percentage Marks**
In-course	Assignment/ Course work	40
	Mid Semester Examination	-
End of Semester Examinations		60

Course Code	**: CE 6209**
Course Title	**: Environmental Technology**
No. of Credits	**: 2**
Pre-requisites	**: None**
Compulsory/Optional	**: Compulsory**

Aim(s): To familiarize with the basic instrumentations, technologies used in Environmental water quality analysis and improve the knowledge on Environmental issues.

Intended Learning Outcomes:

On successful completion of the course, the student should be able to;

1. Explain global environmental issues and suggest mitigation and controls.
2. Perform major water quality measuring experiments and explain the working mechanisms of water quality measuring equipment.
3. Describe the behaviors of microorganisms in geochemical cycle.
4. Design systems that used in Environmental Biotechnology in some important industrial processes.

Time Allocation (Hours)	Lectures: 16 Tutorials: Practical: 24 Assignments: 04 Independent learning: 56 (Notional hours=100)

Course Content/Course Description:

Global Environmental issues and sustainability:

Global Warming, Discharges of Hazardous air pollutants, Inhabitability of Modern Urban Habitat (heat Island Effect, Noise pollution, Sick building syndrome etc.), Introduction to sustainability, Sustainable development goal, Material Life Cycle

Instrumentation:

Working mechanism behind water quality measuring instruments, Spectrophotometric techniques, Chromatographic techniques, Potentiometric techniques, Mass spectrometry; Laboratory demonstration of instruments, Field level experiments

Environmental Biotechnology:

Role of microorganisms in geochemical cycles, Application of Environmental Biotechnology in Production of biogas, bioethanol, biodiesel and biohydrogen, Molecular approaches in Environmental Engineering and biotechnology

Recommended Texts

Rittmann B.E., McCarty P.L., (2001)."Environmental Biotechnology: Principles and Applications", McGraw-Hill Book Co., New York.

Sawyer C., McCarty P., Parkin G., (2003). "Chemistry for Environmental Engineering and Science", 5th Edition, McGraw-Hill Higher Education, New York.

Baird R.B., Eaton A.D., Rice E.W., (2017)."Standard Methods for the Examination of Water and Wastewater", American Public Health Association (APHA), the American Water Works Association (AWWA), and the Water Environment Federation (WEF), 23rd Edition.

Assessment		**Percentage Marks**
In-Course	Assignment/ Course work	50
End of Semester Examinations		50

Course Code	**: CE 6210**
Course Title	**: Geographic Information Systems and Remote Sensing in Water Resources**
No. of Credits	**: 2**
Pre-requisites	**: None**
Compulsory/Optional	**: Optional**

Aim(s): To equip students with knowledge and skills on the applications of geographic information systems (GIS) and Remote Sensing (RS) in water resources management and planning.

Intended Learning Outcomes:

On successful completion of the course, the student should be able to;

1. Explain the basic principles and procedures in geographic data processing
2. Develop practical skills in GIS data formats, data collection methods, data entry and manipulation, coordinate systems and map projections, methods of spatial and 3D analysis and geovisualization.
3. Explain the physical principles underlying remote sensing and apply digital image processing techniques
4. Describe the operation of available Global Navigation Satellite Systems (GNSS) and the error sources.

Time Allocation (Hours)	Lectures: 15 Tutorials: Practical: 15 Assignments: 15 Independent learning: 55 (Notional hours=100)

Course content/Course Description:

Introduction to GIS and software:

Raster data, Vector data, Data structures, Data manipulation, Exploring the interface and file management system

Spatial data structures and sources:

Map projections/coordinate system, World and National datum and transformations, Web and other spatial data sources

GIS analysis functions and operations:

Creating editing and GIS data, Spatial and overlay analysis , Distance analysis, Application of Hydrology tools

Layouts, reports, graphs and data interoperability:

Preparing and presenting maps and tables and exporting them to different online formats, Exporting and importing data to and from different formats

Remote Sensed Data and Image processing techniques:

Use of Elector Magnetic Spectrum in RS, Active and passive remote sensing, Supervised and unsupervised classification, remote sensing application in water resources

Introduction to Geographic Positioning Systems:

GNSS for GIS data capture, importing and exporting GPS data

Recommended Texts

Johnson L.E., (2009). "Geographic Information Systems in Water Resources Engineering", 1st edition, Taylor & Francis Group.

Law M., Collins A., (2013). "Getting to Know ArcGIS for Desktop", 3rd edition, Esri press.

Assessment		**Percentage Marks**
In-course	Assignment/ Course work	60
End of Semester Examinations		40

Course Code	**: CE 6211**
Course Title	**: Groundwater Hydrology**
No. of Credits	**: 2**
Pre-requisites	**: None**
Compulsory/Optional	**: Optional**

Aim(s): To impart knowledge on the essential concepts and computation techniques in groundwater hydrology for engineering applications in environmental and water engineering.

Intended Learning Outcomes:

On successful completion of the course, the student should be able to,

1. Identify porous medium properties that control groundwater flow and transport.
2. Apply groundwater flow equations to confined and unconfined aquifers.
3. Perform test to determine aquifer properties and analyse subsurface contaminant transport and suggest suitable remediation techniques.
4. Identify suitable groundwater basin management strategies.
5. Assess saline water intrusion scenarios and suggest suitable control technologies.

Time Allocation (Hours)	Lectures:24 Tutorials:03 Practical: Assignments:06 Independent learning: 67 (Notional hours = 100)

Course content/Course Description:

Movement of Groundwater:

Steady state and transient groundwater flow in confined and unconfined aquifers

Well Hydraulics:

Steady and unsteady radial flow, Multiple well systems, Wells near aquifer boundaries, Pump tests

Groundwater contamination and remediation:

Groundwater quality, Contamination sources, Mechanisms of contamination, Remediation technologies, Groundwater basin management

Saline water intrusion:

Occurrence of saline water intrusion; Fresh-Saline water interface, Upconing, Control technologies

Computer-Assisted groundwater flow modeling:

Modeling process, Computer models, Model calibration and parameter estimation.

Hydrogeology:

Surface investigation of groundwater, Subsurface investigation of groundwater, Artificial recharge of groundwater.

Recommended Texts

Fits C.R., (2013). "Groundwater Science", 2nd Edition, Elesevier, USA.

Todd D.K., (2003). "Groundwater Hydrology", 2nd Edition, John Wiley & Sons, New York.

Assessment		**Percentage Marks**
In-course	Assignment/ Course work	40
	Mid Semester Examination	-
End of Semester Examinations		60

Course Code	**: CE 6212**
Course Title	**: Hydraulic Structures**
No. of Credits	**: 2**
Pre-requisites	**: None**
Compulsory/Optional	**: Optional**

Aim(s): To impart knowledge on the planning, application of hydraulic structures in water resources management.

Intended Learning Outcomes:

On successful completion of the course, the student should be able to,

1. Explain fluid mechanics and hydraulics concepts applied in planning and design of hydraulic structures.
2. Explain the natural behavior of water bodies/flows and approach for water resources management in harmony with natural environments.
3. Analyze and design different hydraulic structures in water resources development (irrigation, water supply), flood mitigation, coastal zone management for sustainable development.

Time Allocation (Hours)	Lectures: 25 Tutorials: 03 Practical: Assignments: 04 Independent learning: 68 (Notional hours = 100)

Course content/Course Description:

River engineering:

River hydraulics, River morphology, River training, dredging & bank protection, Physical and mathematical models, Environmental aspects in river management

Inland hydraulic structures:

Water retaining, water conveyance and drainage structures and their designs, Flow regulators, Sediment management, Environmental implications of hydraulic structures

Coastal structures:

Physical features of coasts and near shore processes, Shore protection structures, Land reclamations

Recommended Texts

Birdie G.S., Das R.C., (2006). "Irrigation Engineering", DhanpatRai Publishing Company, New Delhi.

French P.W., (2002). "Coastal Defences: Processes, Problems And Solutions", 1st edition, UK: Routledge.

Garg S.K., (2006). "Irrigation Engineering and Hydraulic Structure", Khanna Publishers, New Delhi.

Novak P., Moffat A., Nalluri C., Narayanan R., (2007). "Hydraulic Structures", Taylor & Francis, London, UK.

Ljubomir Tanchev, (2014), "Dams and Appurtenant Hydraulic Structures", 2nd edition, CRC Press.

James C.S., (2020), "Hydraulic Structures", Springer Nature Switzerland AG.

Assessment		**Percentage Marks**
In-course	Assignment/ Course work	40
	Mid Semester Examination	-
End of Semester Examinations		60

Course Code	**: CE 6213**
Course Title	**: Industrial Waste Management**
No. of Credits	**: 2**
Pre-requisites	**: CE 6204**
Compulsory/Optional	**: Optional**

Aim(s): To make students familiarize with industrial processes, associated waste streams, pollution control concepts and techniques by introducing industrial waste management options and legal &policy aspects.

Intended Learning Outcomes:

On successful completion of the course, the student should be able to;

1. Recognize the need for monitoring, reporting and controlling industrial waste systems in relation to national, regional and international policy and legal aspects.
2. Identify and apply in-plant industrial waste management strategies to develop and design industrial waste management programs giving emphasis to best available and application of environmental management systems.
3. Plan, design and execute industrial waste management programs.
4. Evaluate and design industry specific waste treatment technologies.
5. Discuss air pollution monitoring and control systems.

Time Allocation (Hours)	Lectures: 24 Tutorials: 01 Practical: Assignments: 10 Independent learning: 65 (Notional hours=100)

Course Content/Course Description:

Introduction to industrial waste management :

Industrial processes, Industrial waste characterization/testing, Basic industrial waste management concepts and national, regional and international rules and agreements

In-plant waste management:

Waste Minimization, Life cycle assessment, Cleaner Production, Reclamation and Reuse, Environmental Management Systems and related case studies, ISO standards

Industrial waste management:

Primary, secondary and tertiary wastewater treatment unit processes for industrial wastewater treatment (with special emphasis on physical and chemical unit processes)

Industrial solid and sludge management (Control of sludge generation and industrial sludge treatment and reuse)

Air Pollution Monitoring and Control:

Sources of air pollution, Technologies for monitoring and control of air pollution

Recommended Texts

EddyM.,Tchobanoglous G., Stense H.D., Tsuchihashi R., Burton F., Burton F.L., (2013). "Wastewater Engineering: Treatment and Reuse", 5th edition, McGraw-Hill.

Kuhre W.L., (1995). "ISO 14001 Certification - Environmental Management Systems: A Practical Guide for Preparing Effective Environmental Management Systems", Prentice Hall International.

Ranade V.V.,Bhandari V.M., (2014)."Industrial Wastewater Treatment, Recycling and Reuse", 1st edition, Elsevier.

Tchobanoglous G., (2015). "Integrated Solid Waste Management Engineering Principles and Management Issues", McGraw-Hill.

Water Environment Federation, (2008). "Industrial Wastewater Management, Treatment, and Disposal -Manual of Practice", 3rdedition WEF.

Assessment		**Percentage Marks**
In-Course	Assignment/ Course work	40
End of Semester Examinations		60

Course Code	**: CE 6214**
Course Title	**: Integrated Water Resources Management**
No. of Credits	**: 2**
Pre-requisites	**: None**
Compulsory/Optional	**: Optional**

Aim(s): To equip the students with the knowledge for improved water resources management through the implementation of applicable and effective integrated management tools and techniques.

Intended Learning Outcomes:

On successful completion of the course, the student should be able to;

1. Interpret and recommend improved water resources management measures through the implementation of applicable and effective integrated management tools and techniques.
2. Critically analyse the principles of governance, planning, adaptive management and capacity building in local, regional and trans boundary water resources regimes.
3. Assess the concept of integrated water resources management in relation to climate change.

Time Allocation (Hours)	Lectures: 25 Tutorials: 03 Practical: Assignments:04 Independent learning: 68 (Notional hours=100)

Course content/Course Description:

Basic concepts:

Components and dimensions of IWRM

Protection of water resources:

Demand and supply management, Catchment management and recycling and reuse.

Gender in IWRM:

Mainstreaming gender and IWRM nexus, Gender differential roles

Climate change and impacts on water

Water governance:

Regulations and policy, Management of shred water resources.

Water and ecosystems:

Ensuring water quality, Water supply, Sanitation and health, Pollution control and prevention of waterborne diseases

Recommended Texts

Adamowski J., Zyla C., Cuenca E., Medema W., Clamen M., Reig P., (2013).“Integrated and Adaptive Water Resources Planning, Management, and Governance”, Water Resources Publications LLC, Littleton, Colorado, USA.

Grigg N.S., (2016).“Integrated Water Resources Management: An Interdisciplinary Approach”, Palgrave Macmillan, UK.

Assessment		**Percentage Marks**
In-course	Assignment/ Course work	40
	Mid Semester Examination	-
End of Semester Examinations		60

Course Code	**: CE 6215**
Course Title	**: Irrigation and Drainage Engineering**
No. of Credits	**: 2**
Pre-requisites	**: None**
Compulsory/Optional	**: Optional**

Aim(s): To impart knowledge on the essential concepts in the field of irrigation and drainage engineering to design and manage efficient irrigation and drainage systems.

Intended Learning Outcomes:

On successful completion of the course, the student should be able to,

1. Plan, design, manage and operate irrigation systems.
2. Analyse and design surface irrigation systems and sprinkler irrigation systems at field level.
3. Plan and design irrigation structures used for water diversion, regulation and cross drainage purposes.
4. Plan, design and manage land drainage systems in agricultural fields.

Time Allocation (Hours)	Lectures: 25 Tutorials: 03 Practical: Assignments: 04 Independent learning: 68 (Notional hours = 100)

Course content/Course Description:

Irrigation Project Planning:

Project identification, Water availability, Performance and economic aspects of irrigated agriculture, Performance indicators

Irrigation Methods and Design:

Crop water requirement, Irrigation water requirement, Infiltration characteristics of soils for irrigation designs, Design of surface, overhead and drip irrigation systems

Irrigation Water Management:

Water delivery systems, Yield response to water, Irrigation scheduling techniques, Deficit irrigation strategy, Modern irrigation systems

Sustainable Irrigation Systems:

Ancient irrigation systems, Recycling of irrigation water, Environmental aspects of irrigation projects, Ground water pollution control

Drainage Requirements and Systems:

Causes of water logging, Types of drainage systems, Layout and design of drainage systems and their operation and maintenance

Recommended Texts

Garg S.K., (1987). "Irrigation Engineering and Hydraulic Structures", Khanna Publishers.

Sharma R.K., Sharma T.K., (1991). "Irrigation and Drainage Engineering", Oxford & IBH Publishing Co Pvt. Ltd.Michael A.M., (1978). "Irrigation Theory & Practices", Amazing Books International, India.

A.L. Asawa, (2008), "Irrigation and Water Resources Engineering, New Age International (P) Limited, Publishers.

Waller, Peter, Yitayew, Muluneh, (2015), Irrigation and Drainage Engineering, Springer.

Assessment		**Percentage Marks**
In-course	Assignment/ Course work	40
	Mid Semester Examination	-
End of Semester Examinations		60

Course Code	**: CE 6216**
Course Title	**: Public Health Engineering**
No. of Credits	**: 2**
Pre-requisites	**: None**
Compulsory/Optional	**: Optional**

Aim(s): To provide essential concepts related to water and sanitation, household water treatment, water and sanitation systems for rural and peri-urban areas, water safety plans, sanitation safety plans and quantitative risk assessment.

Intended Learning Outcomes:

On successful completion of the course, the student should be able to;

1. Describe the importance of WASH - Explain the link between water contamination, good hygiene practices and health, Disease transmission routes and options for breaking transmission routes.
2. Plan and design hygiene promotion, water supply schemes and appropriate sanitation systems.
3. Develop water safety plans and sanitation safety plans and quantitative risk assessment techniques.

Time Allocation (Hours)	Lectures: 24 Tutorials: 01 Practical: Assignments: 10 Independent learning: 65 (Notional hours=100)

Course content/Course Description:

Global sanitation and health :

Safe water, sanitation and health consequences in the world, Major water, sanitation and hygiene related diseases, their modes of transmission and appropriate options for breaking the transmission routes

Good WASH practices :

Multi barrier approach for safe water (select and design low cost water supply systems), Safe water storage and handling, Hygiene promotion, Sanitation ladder

Sanitation safety plans :

Principles of excreta management, Fecal sludge management (e.g. pond systems, anaerobic digestion)

Introduction to water safety plans and Emergency water supply systems (disasters) Quantitative microbial risk assessment techniques

Recommended Texts

Evans B., Mara D., (2013). "Sanitation and Water Supply in Low Income Countries", 1st edition, ISBN: 978-87-7681-866.

Tilley E., Ulrich L., Lüthi C., Reymond P., Zurbrügg C., (2014). "Compendium of Sanitation Systems and Technologies", IWA, eawag.

Assessment		**Percentage Marks**
In-course	Assignment/ Course work	40
End of Semester Examinations		60

Course Code	**: CE 6217**
Course Title	**: Solid Waste Management**
No. of Credits	**: 2**
Pre-requisites	**: None**
Compulsory/Optional	**: Optional**

Aim(s): To provide knowledge on technical aspects and the management of solid wastes.

Intended Learning Outcomes:

On successful completion of the course, the student should be able to;

1. Explain the implications of generation, management and environmental impacts of solid waste management.
2. Describe main features of an integrated solid waste management system and its associated processing techniques that are intended to minimize the adverse effects.
3. Assess the benefits that can be generated from Solid Waste through various management approaches.
4. Perform basic calculations for sanitary landfills, composting and recycling systems.

Time Allocation (Hours)	Lectures: 23 Tutorials:01 Practical: Assignments:12 Independent learning: 64 (Notional hours=100)

Course content/Course Description:

Introduction to Solid Waste Management:

Waste quantity and quality, Classification of waste, Waste generation rates, Legislation, regulation and control

Waste Collection & Transport:

Collection of mixed waste or of source separated waste, Collection logistics (root planning etc.), Transfer stations, Case study

Treatment/disposal Technologies:

Dumping, Sanitary landfills, Mechanical-biological treatment, Incineration, Anaerobic digestion, Composting; Reduce , reuse and recycling

Green House Gas emission:

Clean Development Mechanism, Energy recovery, Hazardous waste management

Recommended Texts

Chandrappa R., Das D.B., (2012). "Solid Waste Management: Principles and Practice", Springer.
Tchobanoglous G., Kreith F., (2002). "Handbook of Solid Waste Management", McGraw Hill.
Tchobanoglous G., Theisen H., Vigil S.A., (1993). "Integrated Solid Waste Management: Engineering Principles and Management Issues", McGraw-Hill.

Assessment		**Percentage Marks**
In-course	Assignment/ Course work	40
End of Semester Examinations		60

Course Code	: CE 6103
Course Title	: Advanced Study
No. of Credits	: 5
Pre-requisites	: None
Compulsory/Optional	: Compulsory

Aim(s): To train the students to carry out literature review, identify a knowledge gap/complex engineering problem, formulate a methodology, execute the methodology and present the findings.

Intended Learning Outcomes:

On successful completion of the course, the student should be able to;

1. search for technical literature, formulate a research problem based on the identified knowledge gap/complex engineering problem and develop appropriate methodology.
2. carry out a comprehensive analysis to solve the identified research problem/complex engineering problem.
3. write the report and present the research findings/solution to the complex engineering problem in a precise and coherent manner.

Time Allocation (Hours)	Notional hours = 500

Course Content/Course Description:

Self-studies:

Search of technical literature, identify the knowledge gap/complex engineering problem, formulate aim, objectives and scope, develop a methodology, collect data, comprehensive analysis of the research problem/complex engineering problem and present the findings in the form of presentations and a report.

Meetings with supervisor:

Conduct progress meetings with the supervisor, discuss the progress, and receive feedback from the supervisor for the presentation and report.

Recommended Texts

Geoffrey R.M., David D., David F., (2005). "Essentials of Research Design and Methodology", John Wiley & Sons.

Creswell J. W., David J. C., (2017). "Research Design: Qualitative, Quantitative, and Mixed Methods", John SAGE Publications.

Assessment	**Percentage Mark**
In-Course **Progress evaluations:** **Four progress evaluations:** Progress evaluation 1: Oral presentation 1 Progress evaluation 2: Oral presentation 2 Progress evaluation 3: Oral presentation 3 Progress evaluation 4: Oral presentation 4 (After submission of detailed proposal)	40
Detailed Proposal: Detailed Proposal (after three progress presentations) defended before continuing with the advanced study	10

Final Evaluation: Final report Presentation	 30 20