M.Tech.

IN

WATER RESOURCES ENGINEERING

CURRICULUM & SYLLABI

(Applicable from 2023 admission onwards)

तमसो मा ज्योतिर्गमय

Department of Civil Engineering
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
Kozhikode - 673601, KERALA, INDIA

Program Educational Objectives (PEOs) of M.Tech. in Water Resources Engineering

PEO1	Demonstrate advanced knowledge in Water Resources Engineering, enabling them to excel in their profession and pursue higher academic goals.
PEO2	Exhibit strong communication, technical writing and interpersonal skills.
PEO3	Be strongly committed to ethical practices, adherence to quality and performance standards, the society, sustainability, and self-directed life-long learning

Programme Outcomes (POs) & Programme Specific Outcomes (PSOs) of M.Tech. in Water Resources Engineering

PO1	Ability to independently carry out research / investigation and development work to solve practical problems.
PO2	Ability to write and present a substantial technical report / document.
PO3	Demonstrate a degree of mastery over the area as per the specialisation of the programme.
PSO1	Ability to address environmental concerns and sustainability issues related to water resources infrastructure development.
PSO2	Ability for life-long learning of new and innovative technologies in the field of Water Resources Engineering

CURRICULUM

Total credits for completing M.Tech. in Water Resources Engineering is 75.

COURSE CATEGORIES AND CREDIT REQUIREMENTS:

The structure of M.Tech. programme shall have the following Course Categories:

Sl. No.	Course Category	Minimum Credits
1.	Program Core (PC)	20
2.	Program Electives (PE)	18
3.	Institute Elective (IE)	2
4.	Projects	35

The effort to be put in by the student is indicated in the tables below as follows:
L: Lecture (One unit is of 50 minute duration)
T: Tutorial (One unit is of 50 minute duration)
P: Practical (One unit is of one hour duration)
O: Outside the class effort / self-study (One unit is of one hour duration)

PROGRAMME STRUCTURE

Semester I

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	CE6501E	Advanced Fluid Mechanics	3	0	0	6	3	PC
2.	CE6502E	Surface Water Hydrology and Hydrologic Systems	3	0	0	6	3	PC
3.	CE6503E	Remote Sensing and GIS Applications in Water Resources Engineering	3	0	2	7	4	PC
4.	******	Elective I	3	0	0	6	3	PE
5.	******	Elective II	3	0	0	6	3	PE
6.	******	Elective III	3	0	0	6	3	PE
7.		Institute Elective (Entrepreneurship,Research Methodology, Communicative English etc)					2	IE
		Total					**21**	**--**

Semester II

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	CE6511E	Water Resources Systems Analysis and Design	3	0	0	6	3	PC
2.	CE6512E	Flow and Transport in Porous Media	3	0	0	6	3	PC
3.	CE6513E	Computational Hydraulics and Hydrology	3	0	0	6	3	PC

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
4.	******	Elective IV	3	0	0	6	3	PE
5.	******	Elective V	3	0	0	6	3	PE
6.	******	Elective VI	3	0	0	6	3	PE
7.	CE6591E	Water Resources Engineering Laboratory	0	0	2	1	1	PC
8.	CE6596E	Project Phase I				6	2	PC
Total							**21**	**--**

Semester III

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	CE7597E	Project Phase II or Internship				9	3	PC
2.	CE7598E	Project Phase III or Internship				45	15	PC
Total							**18**	**--**

Semester IV

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	CE7599E	Project Phase IV or Internship				45	15	PC
Total							**15**	**--**

List of Department Electives

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	CE6521E	Statistical Methods in Hydrology	3	0	0	6	3
2.	CE6522E	Hydraulic Modelling	3	0	0	6	3
3.	CE6523E	Finite Element Method in Hydro Engineering	3	0	0	6	3
4.	CE6524E	Applied Hydraulic Modelling	3	0	0	6	3
5.	CE6525E	Hydrogeology and Groundwater Development	3	0	0	6	3
6.	CE6526E	Environmental Impact Assessment of Water Resources Projects	3	0	0	6	3
7.	CE6527E	Water Quality Modelling	3	0	0	6	3
8.	CE6528E	Hydropower	3	0	0	6	3
9.	CE6529E	Watershed Management	3	0	0	6	3
10.	CE6530E	Environmental Hydraulics	3	0	0	6	3
11.	CE6531E	Soft Computing in Water Resources Engineering	3	0	0	6	3
12.	CE6532E	Urban Hydrology and Drainage	3	0	0	6	3

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
13.	CE6533E	Coastal Engineering and Coastal Zone Management	3	0	0	6	3
14.	CE6534E	Pollution Science and Engineering	3	0	0	6	3
15.	CE6535E	Hydroclimatology	3	0	0	6	3
16.	CE6536E	Disaster Management	3	0	0	6	3
17.	CE6537E	Environmental Flows	3	0	0	6	3
18.	CE6538E	Dam Safety	3	0	0	6	3

List of Institute Electives

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	IE 6001E	Entrepreneurship Development	2	0	0	4	2
2.	MS6174E	Technical Communication and Writing	2	1	0	4	2
3.	ZZ6002E	Research Methodology	2	0	0	4	2

CE6501E ADVANCED FLUID MECHANICS

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Formulate fluid flow problems in mathematical terms
CO2: Analyse and solve fluid flow problems
CO3: Apply superposition principle to describe fluid flow

Stress at a point for a stationary or uniformly moving fluid, and for nonviscous flows. Stress transformation for viscous fluid motion. Acceleration of a fluid particle. Irrotational flow and its relation to viscosity. System approach and control volume approach. Reynolds transport equation. Basic laws for finite systems and finite control volumes. Conservation of mass. Linear momentum for control volumes fixed in inertial space. Moment of momentum for systems and inertial control volumes. Moment of momentum equation applied to pumps and turbines. Differential forms of the basic laws – conservation of mass, Newton’s laws, Euler equation, Bernoulli’s equation.

General incompressible viscous flow – Navier-Stokes equation. Navier-Stokes equation for laminar incompressible flow. Parallel steady laminar flow problems – flow between infinite parallel plates, flow in pipes, flow in an annulus, Couette flow. Simplified Navier-Stokes equation for a very thin layer of flow. Dynamic similarity law from Navier Stokes equation. Turbulent flow – mean time averages for steady turbulent flow. Navier-Stokes equation for mean time average quantities. Apparent stress. Eddy viscosity.

Potential flow – Mathematical considerations. Circulation. Stokes’ theorem. Circulation in irrotational flows. Velocity potential. Stream function and its relation with velocity field. Stream lines. Two dimensional sources and sinks. Simple vortex. Doublet. Superposition of 2D flows – sink plus vortex, flow about a cylinder without circulation. Rotating cylinder. Lift and drag for a cylinder with circulation. Axisymmetric 3D flows. Stokes’ stream function. Relation between stream line, stream function, and velocity field. 3D sources and sinks. 3D doublet. Steady flow about a sphere.

References

1. I. H. Shames, *Mechanics of Fluids*, McGraw-Hill, Inc., 4th edition, 2002
2. W. P. Graebel, *Advanced Fluid Mechanics*, Elsevier, 1st edition, 2007
3. H. R. Vallenetine, *Applied Hydrodynamics*, Springer, 1st edition, 1967
4. I. G. Currie, *Fundamental Mechanics of Fluids*, CRC, Taylor and Francis, 3rd edition, 2003

CE6502E SURFACE WATER HYDROLOGY AND HYDROLOGIC SYSTEMS

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Perform hydrologic analysis and computations related to precipitation and losses
CO2: Estimate runoff from a watershed
CO3: Carryout flow routing in reservoirs and rivers

Hydrologic cycle, Systems concept, Hydrologic system model, Hydrologic model classification.
Hydrologic Processes – Continuity equations, Momentum Equations, Energy balance
Precipitation – Rainfall characteristics, Development of a design storm, Depth-Area Adjustment, Average areal rainfall, Estimating missing rainfall data, Gauge consistency
Infiltration – Process, Factors affecting infiltration, Measurement, Modelling – Richard's equation, Green-Ampt model, Philip Two Term model, SCS model
Evaporation and Transpiration – Factors affecting evaporation, Measurement, Transpiration, Evapotranspiration, Penman equation

Interception and Depression storage – Factors affecting interception, Estimation of interception, Factors affecting depression storage, Estimation of depression storage. Streamflow – Sources of streamflow, Streamflow hydrograph, Excess rainfall and direct runoff
Hydrograph analysis – Baseflow separation, Estimation of initial abstraction, Separation of losses and rainfall excess, separation of losses using infiltration capacity curves, Introduction to unit hydrograph, Rainfall excess reciprocal method, S-hydrograph method. Snowfall and Snowmelt

Watershed concepts and modelling
Flood routing – Hydrologic and hydraulic routing, Hydrologic river routing, Hydrologic reservoir routing, Governing equations for hydraulic river routing, Kinematic wave routing, Hydraulic river routing.
Hydrologic simulation models – steps in watershed modelling, description of major hydrologic models, HEC flood hydrograph models
Design of drainage collection systems

References

1. V. T. Chow, D. R. Maidment, and L. W. Mays, *Applied Hydrology*, McGraw Hill, First edition, 2017
2. R. H. Mccuen, *Hydrologic Analysis and Design*, Pearson, 4th edition, 2016
3. V. P. Singh, *Elementary Hydrology*, Prentice Hall, 1991
4. P. B. Bedient, W. C. Huber, and B. E. Vieux, *Hydrology and Floodplain Analysis*, Prentice Hall, 5th edition, 2012
5. E. M. Shaw, K. J. Beven, N. A. Chappell, and R. Lamb, *Hydrology in Practice*, 4th edition, CRC press, 2011
6. D. R. Maidment (ed.), *Handbook of Hydrology*, 1st edition, McGraw-Hill Education, 1992
7. V. P. Singh, (ed.), *Handbook of Applied Hydrology*, 2nd edition, Mc Graw Hill, 2017

CE6503E REMOTE SENSING AND GIS APPLICATIONS IN WATER RESOURCES ENGINEERING

L	T	P	O	C
3	0	2	7	4

Prerequisites: Nil

Total Sessions: 65 (Lecture-39, Practical-26)

Course Outcomes:

CO1: Understand the principles of remote sensing and select appropriate remote sensing data for the intended application.
CO2: Perform digital image analysis to extract data from the remote sensing images.
CO3: Carryout spatial analysis by understanding the principles of GIS and basic GIS operations.
CO4: Apply remote sensing and GIS techniques for solving problems in the field of water resources engineering.

Remote Sensing Concepts

Concepts and foundations of remote sensing- Energy sources and radiation principles- Energy interactions in the atmosphere – Energy interaction with earth surface features - Spectral reflectance of vegetation, soil and water - Atmospheric influence on spectral response patterns

Remote Sensing Satellites

Remote sensing platforms – Sun synchronous systems- Geosynchronous systems-Across track and along track scanning systems – Types of sensor resolutions (Spatial, Spectral, Radiometric and Temporal resolution) – Mutispectral and thermal scanners – Characteristics of Remote sensing satellites and sensors (IRS, Landsat, SPOT, IKONOS)

Microwave remote sensing – Active and Passive remote sensing systems - Radar development – Side looking Radar System Operation - Synthetic Aperture Radar – Geometric characteristics of side-looking Radar imagery

Satellite Image Interpretation

Visual Image Interpretation – Standard False Colour Composites – Elements of visual image interpretation

Digital Image Analysis

Digital Image Processing – Storage formats (BSQ, BIL, BIP) – Sources for Geometric and Radiometric distortions in images – Image rectification and restoration – Image histogram – Image enhancement – level slicing, contrast stretching, convolution filtering, Band ratioing (NDVI, SAVI, NDWI) – Image classification – Supervised and unsupervised classification algorithms – Accuracy assessment – land use/ land cover mapping - Principal component transformation

Digital Elevation Models – SRTM, LIDAR Techniques

Concepts of GIS

GIS - Definition, Spatial and attribute data, Components of GIS, DBMS – Geospatial data representation (Raster, Vector) -Sources of GIS data – Data input - Raster geospatial data analysis - Output functions of raster geoprocessing – Vector GIS analysis functions - Vector geoprocessing output functions

Applications

Application of Remote Sensing and GIS with specific reference to land use land cover mapping hydrological modelling and watershed management, drainage delineation, soil moisture estimation, DEM Applications

Practical Exercises: (13 Sessions)

1. Preparation of Standard False Colour Composite (SFCC) and visual interpretation
2. Application of various radiometric enhancements – contrast enhancement, histogram equalization
3. Application of geometric enhancements – image domain - convolution filtering
4. Preparation of vegetation indices
5. Image registration/geo-referencing and supervised classification – Land use /Land cover map preparation
6. Unsupervised classification – Land use /Land cover map preparation
7. Digitization and preparation of vector GIS database of well locations, drainage network, water bodies etc
8. Generating DEM and groundwater contours using spatial interpolation techniques
9. Extraction of drainage network from DEM and watershed delineation using GIS
10. Computation of Area-Capacity for a reservoir using GIS

References

1. T. M. Lillesand, R. W. Kiefer and J. W. Chipman, *Remote Sensing and Image Interpretation*, John Wiley and Sons, Inc., Sixth Edition, 2011
2. J. R. Jenson, *Remote Sensing of the Environment: An Earth Resource Perspective*, Pearson Education India, Second edition, 2013
3. G. Joseph and C. Jeganathan, *Fundamentals of Remote Sensing*, Universities Press, Third edition, 2018
4. J. A. Richards and X. Jia, *Remote Sensing Digital Image Analysis: An Introduction*, Springer (Sge), Fifth Edition, 2013
5. C. P. Lo and K. W. Yeung, *Concepts and Techniques of Geographic Information Systems,* Pearson Education, Second edition, 2016

IE 6001E ENTREPRENEURSHIP DEVELOPMENT

L	T	P	O	C
2	0	0	4	2

Pre-requisites: Nil

Total Lecture Sessions: 26

Course Outcomes:

CO1: Describe the various strategies and techniques used in business planning and scaling ventures
CO2: Apply critical thinking and analytical skills to assess the feasibility and viability of business ideas
CO3: Evaluate and select appropriate business models, financial strategies, marketing approaches, and operational plans for startup ventures
CO4: Assess the performance and effectiveness of entrepreneurial strategies and actions through the use of relevant metrics and indicators

Entrepreneurial Mindset and Opportunity Identification
Introduction to Entrepreneurship Development - Evolution of entrepreneurship, Entrepreneurial mindset, Economic development, Opportunity Recognition and Evaluation - Market gaps - Market potential, Feasibility analysis - Innovation and Creativity in Entrepreneurship - Innovation and entrepreneurship, Creativity techniques, Intellectual property management.

Business Planning and Execution
Business Model Development and Validation - Effective business models, Value proposition testing, Lean startup methodologies - Financial Management and Funding Strategies - Marketing and Sales Strategies - Market analysis, Marketing strategies, Sales techniques - Operations and Resource Management - Operational planning and management, Supply chain and logistics, Stream wise Case studies.

Growth and Scaling Strategies
Growth Strategies and Expansion - Sustainable growth strategies, Market expansion, Franchising and partnerships - Managing Entrepreneurial Risks and Challenges - Risk identification and mitigation, Crisis management, Ethical considerations - Leadership and Team Development - Stream wise Case studies.

References:

1. J. M.Kaplan, A. C. Warren, and V. Murthy (Indian Adoption) *Patterns of entrepreneurship management.* John Wiley & Sons, 2022
2. D. F. Kuratko, *Entrepreneurship: Theory, process, and practic*e. Cengage learning, 2016
3. B. R. Barringer, *Entrepreneurship: Successfully launching new ventures*. Pearson Education India, 2015
4. R. Shah, Z. Gao, H. Mittal, *Innovation, Entrepreneurship, and the Economy in the US, China, and India,* Academic Press, 2014
5 K. Sundar, *Entrepreneurship Developmen*t, 2nd Ed , Vijaya Nichkol Imprints, Chennai, 2022
6 E. Gordon, and K. Natarajan., *Entrepreneurship Development*, 6th Ed, Himalya Publishers, Delhi, 2017
7 D. Biswas, and C. Dey, *Entrepreneurship Development in India*, Taylor & Francis, 2021

MS6174E TECHNICAL COMMUNICATION AND WRITING

L	T	P	O	C
2	1	0	3	2

Pre-requisites: Nil

Total Lecture Sessions: 26

Course Outcomes:

CO1: Apply effective communication strategies for different professional and industry needs
CO2: Collaborate on various writing projects for academic and technical purposes
CO3: Combine attributes of critical thinking for improving technical documentation
CO4: Adapt technical writing styles to different platforms.

Technical Communication
Process(es) and Types of Speaking and Writing for Professional Purposes - Technical Writing: Introduction, Definition, Scope and Characteristics - Audience Analysis - Conciseness and Coherences - Critical Thinking - Accuracy and Reliability - Ethical Consideration in Writing - Presentation Skills - Professional Grooming - Poster Presentations

Grammar, Punctuation and Stylistics
Constituent Structure of Sentences - Functional Roles of Elements in a Sentence - Thematic Structures and Interpretations - Clarity - Verb Tense and Mood - Active and Passive Structures - Reporting Verbs and Reported Tense - Formatting of Technical Documents - Incorporating Visuals Elements - Proofreading

Technical Documentation
Types of Technical Documents: Reports, Proposals, Cover Letters - Manuals and Instructions - Online Documentation - Product Documentation - Collaborative Writing: Tools and Software - Version Control Document Management - Self Editing, Peer Review and Feedback Processes

References:

1. M. Foley, and D. Hall, *Longman advanced learner's grammar, a self-study reference & practice book with answers*. Pearson Education Limited, 2018
2. S. J. Gerson, and S. M. Gerson, *Technical writing: Process and product*. Pearson, 2009
3. Kirkwood, H. M. A., & M., M. C. M. I. *Hallidays introduction to functional grammar* (4th ed.). Hodder Education, 2013
4. M. Markel, *Technical Communication* (10th ed.). Palgrave Macmillan, 2012
5. I. Tuhovsky, *Communication skills training: A practical guide to improving your social intelligence, presentation, Persuasion and public speaking skills.* Rupa Publications India, 2019
6. R. Williams, *The Non-designer's Design Boo*k. Peachpit Press, 2014

ZZ6002E RESEARCH METHODOLOGY

L	T	P	O	C
2	0	0	4	2

Pre-requisites: Nil

Total Lecture sessions: 26

Course Outcomes
CO1: Explain the basic concepts and types of research
CO2: Develop research design and techniques of data analysis
CO3: Present research to the scientific community
CO4: Develop an understanding of the ethical dimensions of conducting research

Exploring Research Inquisitiveness
Philosophy of Scientific Research, Role of Research Guide, Planning the Research Project, Research Process, Research Problem Identification and Formulation, Variables, Framework development, Research Design, Types of Research, Sampling, Measurement, Validity and Reliability, Survey, Designing Experiments, Research Proposal, Research Communication, Research Publication, Structuring a research paper, structuring thesis/ dissertation.

Data Analysis
Literature review :Tools and Techniques, Collection and presentation of data, processing and analysis of data, Descriptive statistics and inferential statistics, Measures of central tendency, dispersion, skewness, asymmetry, Probability distributions, Single population and two population hypothesis testing, Parametric and non-parametric tests, Design and analysis of experiments: Analysis of Variance (ANOVA), completely randomized design, Measures of relationship: Correlation and regression, simple regression analysis, multiple regression, interpretation of results, Heuristics and simulation.

Research writing and Ethics
Reporting and presenting research, Paper title and keywords, writing an abstract, writing the different sections of a paper, revising a paper, responding to peer reviews.

The codes of ethics, copyright, patents, intellectual property rights, plagiarism, citation, acknowledgement, avoiding the problems of biased survey.

References:
1. Krishnaswamy, K.N., Sivakumar, A.I., and Mathirajan, M. (2006). *Management Research Methodology*, Pearson Education.
2. Leedy, P, D. (2018). *Practical Research: Planning and Design* (12 e) Pearson.
3. Kothari, C.R. (2004). Research Methodology – Methods and Techniques, New Age International Publishers.
4. Mike Martin, Roland Schinzinger, (2004) *Ethics in Engineering*, Mc Graw Hill Education
5. Vinod V Sople (2014) *Managing Intellectual Property-The Strategic Imperative*, EDA Prentice of Hall Pvt. Ltd.

CE6511E WATER RESOURCES SYSTEMS ANALYSIS AND DESIGN

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Perform economic analysis to evaluate the economic feasibility of water resources projects
CO2: Formulate and solve water resources problems using various optimization techniques
CO3: Apply various advanced technologies in systems analysis to solve water resources problems

Economic Analysis and Optimization using Calculus
Concept of System and Systems Analysis - definition of a system, types of systems, systems approach, systems analysis. Systems Techniques in Water Resources, Economic Considerations in Water Resources Systems – general principles, discount factors, comparison of alternative plans, market demand and supply, benefit cost analysis
Optimization using Calculus:- optimization of functions of single and multiple variables, Constrained and unconstrained optimisation

Linear Programming and Dynamic programming
Linear programming – problem formulation, simplex method, dual simplex method, sensitivity analysis, Multi objective Planning – noninferior solutions, weighting method and constraint method for plan formulation, plan selection. Dynamic Programming – characteristics of a DP problem, recursive relations, multiple state variables, application of dynamic programming for various multi-stage decision problems in water resources engineering.

Advances in systems analysis
Simulation: Basic principles and concepts – Model development – Inputs and outputs – Single and multipurpose reservoir simulation models – Deterministic simulation, application of evolutionary algorithms like Genetic algorithm, Simulated Annealing to water resources problems, Fuzzy inference system, Introduction to Simulation-Optimization, Optimization and simulation under uncertainties, Application of simulation and optimization techniques to reservoir operation, environmental flow alteration and hydropower.

References

1. S. Vedula, and P. P. Mujumdar, *Water Resources Systems – Modelling Techniques and Analysis*, Tata McGraw-Hill Publishing Company Limited, New Delhi, 1st edition, 2005
2. D. P. Loucks, J. R. Stedinger, D. A. Haith, *Water Resources Systems Planning and Analysis,* Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1981
3. L. W. Mays, and Y-K. Tung, *Hydrosystems Engineering and Management*, McGraw-Hill, Inc., 2002
4. W. A. Hall, and J. A. Dracup, *Water Resources Systems Engineering*, Tata McGraw-Hill Publishing Company Limited, New Delhi, 1970
5. P. R. Bhave, *Water Resources Systems*, Narosa Publishing House, New Delhi., 2011
6. James and Lee, *Water Resources Economics.* Oxford Publishers, 2005

CE6512E FLOW AND TRANSPORT IN POROUS MEDIA

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Formulate and solve governing equations for steady and transient groundwater flow
CO2: Perform groundwater resource estimation and plan schemes for recharge
CO3: Perform numerical modelling of transport problems in the subsurface

Groundwater and the hydrologic cycle. Occurrence and movement of groundwater - origin, age, distribution, types of aquifers. Darcy's law, hydraulic head and fluid potential, hydraulic conductivity and permeability, heterogeneity and anisotropy of hydraulic conductivity, porosity and void ratio, compressibility and effective stress, transmissivity and storativity. Steady State and transient flow - formulation of the governing equations, limitations of the Darcian approach. Groundwater and well hydraulics - steady flow to a well fully penetrating an aquifer (confined and unconfined), unsteady radial flow to a well fully penetrating an aquifer (confined, unconfined and leaky), effect of well bore storage.

Multiple well systems, partially penetrating wells, bounded aquifers, characteristic well losses, specific capacity. Slug tests. Introduction to flow in the unsaturated zone and flow in fractured formations. Saline water intrusion in coastal aquifers: occurrence, shape and structure of the interface, upconing, control of saline water intrusion. Groundwater modelling, Inverse modelling in groundwater. Artificial recharge of aquifers - concepts, hydraulics and methods. Groundwater budget.Groundwater resource estimation.

Introduction to groundwater contamination. Quality of groundwater - measures of quality, groundwater samples, physical, chemical and biological analyses, water quality criteria, and salinity. Transport and transformation of contaminants in groundwater - processes, formulation of the governing equations and initial and boundary conditions, modelling, solutions for simple cases.

References

1. D. K. Todd and L. W. Mays, *Groundwater*, 3rd ed., John Wiley & Sons, Inc., 2011
2. R.A. Freeze and J. A. Cherry, *Groundwater*, Prentice Hall, Inc. 1979
3. C. W. Fetter, *Applied Hydrogeology*, 4th ed., Prentice Hall, Inc. 2007
4. C. W. Fetter, *Contaminant Hydrogeology*, 2nd ed., Waveland Press, 2008
5. F. W. Schwartz and H. Zhang, *Fundamentals of Groundwater*, John Wiley & Sons, Inc., 2003
6. A. K. Rastogi, *Numerical Groundwater Hydrology*, Penram International Publishing (India) Pvt. Ltd., 2007.
7. V. Batu, *Applied Flow and Solute Transport Modeling in Aquifers*, CRC Press, 2006
8. E. S. Bair and T. D. Lahm, *Practical Problems in Groundwater Hydrology*, Prentice Hall, Inc. 2006

CE6513E COMPUTATIONAL HYDRAULICS AND HYDROLOGY

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Solve problems of linear, nonlinear, algebraic, differential and partial differential equations
CO1: Solve fluid flow problems using numerical schemes
CO3: Apply finite difference schemes for modeling open channel flow, groundwater flow and contaminant transport

Introduction to computational methods. Accuracy and precision, definitions of round off and truncation errors, error propagation Linear system-Solution for Banded and Sparse systems using Gaussian elimination and Gauss, Jordan methods, Gauss seidel method – Nonlinear equations –Newton- Raphson methods, interpolation – Newton's and Lagrange's interpolation. Introduction to Finite Differences. Solution of System of Non Linear Algebraic equations using Newton and Picard Method. Numerical solution of Ordinary differential equations-Initial and Boundary value problems, Solutions using Euler Method, Modified Euler Method, Fourth –order Runge-Kutta method. Computation of gradually varied flow using numerical techniques.

Introduction to Partial Differential Equations-Elliptic, Parabolic and Hyperbolic equations. Boundary conditions. Explicit and Implicit Finite Difference schemes. Introduction to Method of Characteristics. Introduction to finite volume method

Application of finite difference method to saturated and unsaturated flow, transport in ground and surface waters - advection, diffusion and advection-diffusion equations, steady and unsteady open channel flows. Convergence, Stability and Consistency of finite difference schemes. Modelling using HEC-RAS, HEC-HMS, MODFLOW and MT3D

References

1. S. C. Chapra and R. P. Canale, *Numerical Methods for Engineers*, McGraw Hill, 7th edition, 2010
2. S. K. Gupta, *Numerical Methods for Engineers*, New Age International Publishers, 2015
3. J. D Anderson, *Computational Fluid Dynamics*, McGraw Hill, 1995
4. C. Zheng and G. D. Bennett, *Applied Contaminant Transport Modeling,* New York: John Wiley & Sons, 2002
5. V. T. Chow, D. R. Maidment, and L. W. Mays, *Applied Hydrology*, McGraw Hill, 1988
6. *Technical Manuals of HEC-RAS, HEC-HMS, MODFLOW*

CE6591E WATER RESOURCES ENGINEERING LABORATORY

L	T	P	O	C
0	0	2	1	1

Prerequisites: Nil

Total Practical Sessions: 26

Course Outcomes:

CO1: Formulate models for simulating flow in pipe networks
CO2: Formulate models for simulating groundwater flows
CO3: Simulate wet weather and dry weather flows in sewers
CO4: Carryout flow routing in channels and reservoirs

Practical Exercises:

1. Flow and transport problems in pipelines
2. Flow and transport problems in open channels including rivers
3. Groundwater flow and transport
4. Flow and transport in the vadose zone
5. Coastal circulation and sediment transport
6. Storm and sanitary sewer design
7. Flow routing in channels and reservoirs
8. Experimental studies on surface water and groundwater flow

References

1. *Technical Manuals of HEC-RAS, HEC-HMS, MODFLOW, EPANET, HYDRUS,DELFT3D*

CE6596E PROJECT PHASE I

L	T	P	O	C
0	0	0	6	2

Prerequisites: Nil

Course Outcomes:

CO1: Identify a relevant problem, carry out literature review and identify the research gaps
CO2: Propose a methodology for solving the problem
CO3: Document and present the work done

The primary objective of the course 'Project Phase I' is to introduce the students to the various areas of research in Hydraulics and Water Resources Engineering. The students will identify a problem, carry out a systematic and exhaustive literature review and identify the research gaps. The students will propose a methodology for solving the identified problem. At the end of the semester, the students will document their work and make a presentation before the designated "Evaluation Committee".

CE7597E PROJECT PHASE II

L	T	P	O	C
0	0	0	9	3

Prerequisites: Nil

Course Outcomes:

CO1: Identify a relevant problem, carry out literature review and identify the research gaps
CO2: Propose a methodology for solving the problem
CO3: Document and present the work done

The student will identify a relevant problem in the broad area of Hydraulics and Water Resources Engineering and work on it. The study could be experimental, analytical, or computational. At the end of summer vacation, the students will document their work and make a presentation before the designated "Evaluation Committee". This also applies to those who take this up as an internship in an industry/ company/ an institute as well.

For students opting for internship course outcomes will depend on the actual work performed during the internship.

CE7598E PROJECT PHASE III

L	T	P	O	C
0	0	0	45	15

Prerequisites: Nil

Course Outcomes:

CO1: Demonstrate their theoretical and research skills to become independent researchers with high ethical values
CO2: Demonstrate a degree of originality in research emphasizing the concept of sustainability
CO3: Develop professional documentation and presentation skills

The student will identify a relevant problem in the broad area of Hydraulics and Water Resources Engineering and work on it. The study could be experimental, analytical, or computational. At the end of the semester, the students will document their work and make a presentation before the designated "Evaluation Committee". This also applies to those who take this up as an internship in an industry/ company/ an institute as well.

For students opting for internship course outcomes will depend on the actual work performed during the internship.

CE7599E PROJECT PHASE IV

L	T	P	O	C
0	0	0	45	15

Prerequisites: Nil

Course Outcomes:

CO1: Demonstrate their theoretical and research skills to become independent researchers with high ethical values
CO2: Demonstrate a degree of originality in research emphasizing the concept of sustainability
CO3: Develop professional documentation and presentation skills

The student will identify a relevant problem in the broad area of Hydraulics and Water Resources Engineering and work on it. The study could be experimental, analytical, or computational. At the end of the semester, the students will document their work and make a presentation before the designated "Evaluation Committee". This also applies to those who take this up as an internship in an industry/ company/ an institute as well.

For students opting for internship course outcomes will depend on the actual work performed during the internship.

CE6521E STATISTICAL METHODS IN HYDROLOGY

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Identify the suitable probability distribution and estimate parameters of hydrologic random variables
CO2: Establish the relationship between two variables
CO3: Analyze and model hydrologic time series

Randomness of hydrologic variables – total probability and Bayes theorems. Univariate, bivariate, marginal and conditional distributions of hydrologic random variables. Independence. Derived and mixed distributions. Properties of hydrologic random variables – moments and expectation, moment generating functions. Measures of central tendency, dispersion, symmetry, and peakedness. Moments and expectation of jointly distributed hydrologic random variables, covariance, correlation coefficient, parameter estimation, Chebyshev inequality.

Discrete Probability Distributions of Hydrologic Random Variables – hypergeometric distributions, Bernoulli process – binomial, geometric, and negative binomial distributions. Poisson process – Poisson, exponential, and gamma distribution, multinomial distribution. Continuous Probability Distributions of Hydrologic Random Variables – general and standard normal distributions, central limit theorem, constructing normal curves for hydrologic data, normal approximations of binomial, negative binomial, and Poisson distributions. Uniform, exponential, gamma, lognormal, extreme value, beta, and Pearson distributions. Chi-square, t-, and F-distributions.

Probability Plotting and Frequency Analysis –probability plotting, analytical hydrologic frequency analysis, regional frequency analysis, frequency analysis of precipitation data and other hydrologic variables. Linear and nonlinear regression, transformation of nonlinear models.Correlation, correlation and regional analysis. Multivariate analysis, principal component analysis, univariate and multivariate data generation.

Hydrologic time series – definition, autocorrelation, spectral analysis, applications of autocorrelation and spectral density functions in hydrology. Stochastic hydrologic models – purely random stochastic models, first order Markov process, first order Markov process with periodicity, higher order autoregression models, multisite Markov model, Markov chain models of hydrologic processes.

References

1. C. T. Haan, *Statistical Methods in Hydrology*, Wiley-Blackwell; 2nd edition, 2002
2. M. Shahin, H. J. L.vanOorschot, and S. J. de Lange, *Statistical Analysis in Water Resources Engineering*, Aa-Balkema, Rotterdam, Brookfield, 1993
3. V. Yevjevich, *Probability and Statistics in Hydrology*, Water Resources Publications, Fort Collins, Colorado, USA, 2nd edition, 2010
4. P. J. Reddy, *A Text Book of Stochastic Hydrology*, Laxmi Publications, New Delhi, 2nd edition, 2016
5. R. Maity, *Statistical methods in hydrology and hydroclimatology,* Singapore: Springer, 2018

CE6522E HYDRAULIC MODELLING

L	T	P	O	C
3	0	0	6	3

Prerequisite: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Perform numerical analysis of problems in Water Resources Engineering
CO2: Develop physical models
CO3: Model the open channel flow
CO4: Model the coastal processes and near shore structures

Review of the theoretical background required for hydraulic modelling – basic mathematics, hydraulics, and numerical techniques.

Development of physical models – dimensional analysis and principles of similitude, non-dimensional numbers employed in hydraulic modelling, tools and procedures.

Modelling of open channel systems, closed conduit systems and urban drainage systems. Environmental modelling of open channel systems.

Modelling of estuaries, coastal processes, nearshore structures, and hydraulics structures.

References

1. P. Novak, V. Guinot, A. Jeffrey, and D. E. Reeve, *Hydraulic Modelling – An Introduction*, Spon Press, 1st edition, 2010
2. J. J. Sharp, *Hydraulic Modelling*, Butterworths, 1981
3. H. Kobus and G. Abraham, *Hydraulic Modelling*, Parey, 1980
4. S. N. Ghosh, *Tidal Hydraulic Engineering*, Oxford and IBH Pub. Co. Pvt. Lt., 1st edition, 2017
5. V. Batu, *Applied Flow and Solute Transport Modeling in Aquifers*, Taylor and Franics, 1st edition, 2005
6. J. L. Martin and S. C. McCutcheon, *Hydrodynamics and Transport for Water Quality Modeling*, Lewis Publishers, 1st edition, 1998

CE6523E FINITE ELEMENT METHOD IN HYDRO ENGINEERING

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Formulate and solve finite element models for flow analysis
CO2: Perform linear and nonlinear analysis of pipe networks
CO3: Perform two dimensional flow analysis
CO4: Carryout isoparametric formulation and numerical integration

Review of Basic Equations of Fluid Mechanics and Pipe Network Analysis, Linear finite element analysis of pipe networks, total system of equations, boundary conditions, solution of system of equations, non-linear analysis of pipe networks, computer algorithms for linear and non-linear analyses.

One-Dimensional Flow Analysis, Interpolation functions, C^m continuity. Governing differential equations, finite element formulations and solutions for (i) laminar flow through pipes, (ii) viscous flow on an inclined flat surface, and (iv) radial flow in an unconfined aquifer.

Two-Dimensional Flow Analysis, Potential Flow Analysis Euler‘s equation of motion, stream function formulation, potential function formulation, finite element solution of groundwater flow and flow around a cylinder.

Isoparametric formulation. Isoparametric triangular and rectangular elements, Numerical integration – Newton Cotes and Gauss-Legendre quadrature formulas, Integration formulas for isoparametric triangular and rectangular elements. Serendipity elements.

References

1. J. N. Reddy, *An Introduction to the Finite Element Method*, McGraw Hill Book Co., 1993
2. S. S. Rao, *The Finite Element Method in Engineering*, Elsevier, 2004
3. O. C. Zienkiewicz, and K. Morgan, *Finite Elements and Approximation*, John Wiley and Sons, 1983
4. O. C. Zienkiewicz, R. L. Taylor, and J. Z. Zhu, *The Finite Element Method – Its Basics and Fundamentals*, Elsevier, 2005

CE6524E APPLIED HYDRAULIC MODELLING

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyse and design water distribution networks
CO2: Analyse and design pipelines for transient flow conditions
CO3: Design open channels and open channel network
CO4: Carryout dam break analysis

Conservation laws - mass, momentum and energy. Governing equations of fluid flow, initial and boundary conditions. Pipe flow - review of basic hydraulic principles of analysis and design of pipelines, losses in pipelines, pumping and gravity mains, economic analysis for pipe choice, pipe materials, specification for pipes, pipe appurtenances, design principles - internal pressures and external loads, analysis of distribution networks - Hardy Cross, equivalent pipe and Newton Raphson methods, computer applications in distribution network analysis, maintenance of distribution systems, methods of control and prevention of corrosion.

Pump-pipeline and turbine-pipeline systems. Transients in pipelines - causes, simple analysis by finite difference method and method of characteristics, transient control using surge tanks, air chambers and control valves

Open channel flow - canal network and hierarchy of canals, afflux and energy loss, critical flow and uniform flow concepts, flow in erodible channels, channel design - design of erodible and lined channels for clear and sediment-laden flows - CBI & P method, tractive force method, regime methods. Gradually varied flow - classification and computation of profiles, compound channels, canal delivery problem, channel networks, spatially varied flow.

Rapidly varied flow - hydraulic jump, analysis of surges, design of spillways, energy dissipators, and channel transitions. Dam break analysis. Main canal and flow distribution control, decentralised control, canal automation - purpose and selection ofscheme, automation application, hardware and software components in automation systems, a typical automation system.

References

1. V. T. Chow, *Open Channel Hydraulics*, Mc Graw Hill, Inc,1st edition, 1959
2. R. H. French, *Open Channel Hydraulics*, Water Resources Pub, 1st edition, 1985
3. M. H. Chaudhry, *Open Channel Flow*, Springer, 2nd edition, 2008
4. H. Chanson, *The Hydraulics of Open Channel Flow – An Introduction*, Elsevier Butterworth-Heinemann, 2nd edition, 2004
5. E. B. Wylie and V. L. Streeter, *Fluid Transients*, Mc Graw Hill, Inc, 2nd edition, 2007
6. M. H. Chaudhry, *Applied Hydraulic Transients*, Van Nostrand Reinhold, 1st edition, 1979
7. J. A. Fox, *Transient Flow in Pipes, Open Channels, and Sewers*, Ellis Horwood, 1st edition, 1989
8. T. M. Walski, *Analysis of Water Distribution Systems*, Van Nostrand Reinhold Co., 1982
9. B. E. Larock, R. W. Jeppson, and G. Z. Watters, *Hydraulics of Pipeline Systems*, CRC Press, 1st edition, 1999
10. T. M. Walski, D. V. Chase, and D. A. Savic, *Water Distribution Modeling*, Haestad Press, 2001
11. CBIP, *Canal Automation*, Publication No. EW-02-11, CBIP, 2011
12. P. R. Bhave and R. Gupta, *Analysis of Water Distribution Networks*, Narosa Publishing House, 2nd edition, 2006

CE6525E HYDROGEOLOGY AND GROUNDWATER DEVELOPMENT

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Perform hydrogeologic investigations for groundwater management
CO2: Select appropriate methods and perform groundwater exploration
CO3: Identify appropriate water lifting devices and design these devices

Groundwater and the hydrologic cycle, problems and perspectives, groundwater balance, status of groundwater development and utilization – international and national scenarios, influence of physiography and climate on groundwater availability, major hydrogeologic formations in India, groundwater quality/ contamination in India. Basic concepts of groundwater management, investigations and data collection, conjunctive use of surface and groundwaters, legal aspects of groundwater. Basic geologic and hydrogeologic investigations including surface and subsurface investigations of groundwater, water divining/witching. Types of wells, design and construction of open wells, open wells in alluvial and hard rock formations, failure of open wells, contamination and disinfection of open wells.

Types of tube wells, multiple well system, radial wells and infiltration galleries, design of tube wells - casing, bore size and depth, design of well screen and gravel pack, contamination of tube wells, failure of tube wells, rehabilitation of tube wells. Construction of bored and driven tube wells – drilling equipment and methods, hand boring, mechanical percussion boring, direct and reverse circulation hydraulic rotary drilling, air rotary drilling, principles of rock drilling, drilling with foam, core drilling, calyx drilling, jetting. Installation of well screens and check for well alignment. Well development and well completion.

Pumps used for lifting water - indigeneous water lifts, positive displacement pumps, centrifugal pumps, vertical turbine pumps, submersible pumps, propeller and mixed flow pumps, jet pumps, air lift pumps, selection of pumps, power requirement, efficiency and economics.

References

1. D. K. Todd and L. W. Mays, *Groundwater*, 3rd ed., John Wiley & Sons, Inc., 2004
2. F. W. Schwartz and H. Zhang, *Fundamentals of Groundwater*, John Wiley & Sons, Inc., 2003
3. S. D. Khepar, A. M. Michael and S. K. Sondhi, *Water Wells and Pumps*, McGraw Hill Education (India) Private Ltd., 2008
4. A. M. Michael, *Irrigation Theory and Practice*, Vikas Publishing House Pvt. Ltd., 2009
5. Robert A. Bisson, Jay H. Lehr, *Modern Groundwater Exploration*, John Wiley & Sons, Inc., 2004
6. K. R. Karanth, *Groundwater Assessment: Development and Management*, Tata McGraw Hill, 1987
7. H. P. Patra, S. K. Adhikari, and Subrata Kunar, *Groundwater Prospecting and Management*, Springer, 2016
8. Websites of the Ministry of Jal Shakthi, Govt. of India, CGWB, and State GWDs.

CE6526E ENVIRONMENTAL IMPACT ASSESSMENT OF WATER RESOURCES PROJECTS

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Carryout baseline studies and select appropriate technique based on the EIA regulations
CO2: Perform EIA studies in a scientific manner
CO3: Prepare an EIS and formulate and EMP

Concept of environment and sustainable development. Environmental impact assessment (EIA) – definitions, terminology and overview. Evolution of EIA – major features of the National Environmental Policy Act and the Council on Environmental Quality guidelines. Role of the USEPA. Generalised EIA process flow chart of the UNEP. Evolution of EIA in India – major features of the EIA notification and its subsequent amendments, implementation of EIA in India. Legislation in India pertaining to environmental pollution and waste management. Steps in EIA such as screening, initial environmental examination (IEE), scoping, public participation. Environmental baseline studies. Impact assessment methods such as adhoc methods, checklists, matrices, quantitative methods, environmental indices, networks, overlay etc. Factors to be considered while assessing the environmental impacts of various infrastructure projects.

Prediction and assessment of impacts on land and soil, groundwater, surface water, air, noise, biological, socio-economic and visual environments (including details of various tools that can be employed for prediction of impacts). Guidelines published by the MoEF&CC regarding EIA of specific projects.

Evaluation of alternatives. Preparing the EIA document/ report, Environmental impact statement (EIS). Strategic environmental impact assessment. Environmental monitoring. Environmental audit (EA). Case studies.

References

1. L. W. Canter, *Environmental Impact Assessment*, McGraw Hill, Inc., 1996
2. B. B. Marriot, *Environmental Impact Assessment: A Practical Guide*, McGraw Hill, Inc., 1997.
3. C. J. Barrow, *Environmental and Social Impact Assessment – An Introduction*, Edward Arnold, 1997
4. R. Therivel and G. Wood (eds.), *Methods of Environmental and Social Impact Assessment (Natural and Built Environment Series)*, 4th ed., Routledge, 2018
5. E. K. Paleologos and I. Lerche, *Environmental Risk Analysis*, McGraw Hill, Inc., 2001
6. UNEP, *Environmental Impact Assessment Training Resource Manual*, 2002
7. Guidelines for EIA published by the Ministry of Environment, Forests, and Climate Change (MoEF & CC), Government of India.
8. J. T. Maughan, *Environmental Impact Analysis: Process and Methods*, CRC Press, 2017
9. Websites of the Ministry of Environment, Forests, and Climate Change (MoEF & CC), Govt. of India, Ministry of Jal Shakthi, Govt. of India, Central Pollution Control Board (CPCB).and State PCBs

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CE6527E WATER QUALITY MODELLING

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Formulate the governing equations for contaminant transport process
CO2: Analyze different modeling approaches for water quality problems in rivers, lakes, estuaries, wetlands, saturated and unsaturated porous media and pipe networks
CO3: Apply the models to solve water quality problems and suggest remedial measures

Water quality, standards, Types of contaminant, contaminants and their harmful effects, fate of contaminants, transformation of contaminants, transport of contaminants, Advection, diffusion, dispersion, simple transport models, chemical reaction kinetics, law of mass action, rate constants, types of reactions, equilibrium principles, Introduction to modeling, brief review of mass, momentum and energy balance, governing equations for contaminant fate and transport, Models for nitrogen, bacteria, phosphate and toxicants.

Contaminant transport in surface flows, rivers, hydrodynamic processes in rivers, eutrophication, dissolved oxygen in rivers, Streeter-Phelps equation, modification to Streeter-Phelps Equation, models for lakes and reservoirs, biological zones in lakes, eutrophication in lakes, hydrodynamic processes in lakes and reservoirs, stratification, models for estuaries, tidal processes, hydrodynamics of estuaries, stratification of estuaries, eutrophication in estuaries, models for wetlands, characteristics of wetland, hydrodynamics of wetlands, constructed wetlands

Transport through saturated porous media, groundwater transport phenomena, Groundwater bio reaction and bio kinetics, hydrodynamic dispersion, initial and boundary conditions, unsaturated porous media, capillarity and retention curves, motion equations, initial and boundary conditions fractured media, multiphase flow, flow behavior in pipe networks, quality attenuation, physical characteristics, chemical and biological reactions

Modeling and Management, different types of models, different numerical methods, finite difference method, solution of system of linear equations, Pipe network modeling (EPANET), surface water quality modeling (QUAL2K), Groundwater modeling (MODFLOW and MT3D), unsaturated zone modeling (SUTRA/HYDRUS), fractured rock (ModelMuse) water quality management, application of optimization techniques to water quality management, case studies.

References

1. S.C. Chapra, *Surface Water Quality Modeling*. Long Grove, Ill.: Waveland Press, 2008.
2. J. Martin, S. McCutcheon and R. Schottman, *Hydrodynamics and Transport for Water Quality Modeling*. Boca Raton, FL: CRC Press, 1st edition, 1998
3. C.Zheng, and G.D. Bennett. *Applied Contaminant Transport Modeling*, 2nd ed. New York: John Wiley & Sons, 2nd edition, 2002.
4. R. Boulding, *Practical Handbook of Soil, Vadose Zone, and Groundwater Contamination*. Boca Raton: Lewis Publishers, 2nd edition, 2004.
5. *Technical Manuals of EPANET, MODFLOW, MT3D, HYDRUS, QUAL2K*

CE6528E HYDROPOWER

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Estimate the water power potential of a stream
CO2: Plan and design different components of a hydel power plant
CO3: Perform flow routing and dam breach analysis

Different sources of energy. Hydropower – Place of hydropower in a power system, global and national status of hydropower development. Fundamentals of water power engineering - classification of hydropower plants. Water power estimates – essentials of streamflow for water power studies. Pondage and storage, effect of pondage on plant capacity, benefits from storage. Basic hydrology - mass curve and flow duration curve, influence of reservoirs on floods. Load curve and load factor, utilization factor, capacity factor, diversity factor. Firm power and secondary power. Prediction of load.

Run of the river plants, pumped storage plants. Mini and micro hydel plants. Tidal power plants. General arrangement of a power house, types of power houses. Hydropower structures – intakes, forebay, gates and valves, penstocks, power canals and tunnels, anchor blocks. Joints. Bends and Manifolds. Water Hammer. Surges and Surge Tanks.

Turbines and Generators. Flood routing through reservoirs and channels. Dam breach analysis. Cost and value of water power.

References

1. M. M. Dandekar and K. N. Sharma, *Water Power Engineering*, Vikas Publishing House (P) Ltd., 2015.
2. R. K. Sharma and T. K. Sharma, *A Textbook of Water Power Engineering*, S. Chand, 2003.
3. M. G. Jog, *Hydro–Electric and Pumped Storage Plants*, New Age International Publishers, 1997.
4. N. Lamba, *Water Power Engineering*, Venus Books, 2014.
5. H. K. Barrows, *Water Power Engineering*, McGraw Hill Inc., 1943.
6. W. P. Creager and J. D. W. Justin, *Hydroelectric Engineering Handbook*, John Wiley and Sons, 1950.
7. E.l Mosonyi, *Water Power Development*, Hungarian Academy of Sciences, 1957.
8. G. Brown, *Hydroelectric Engineering Practice*, Blackie and Sons Ltd; London, 1958.
9. P. S. Nigam, *Handbook of Hydroelectric Engineering,*Nem Chand and Bros., Roorkee, 2008.
10. R. S. Varshney, *Hydro Power Structures*, Nem Chand and Bros., Roorkee, 2014.
11. R. S. Varshney, *Gates and Valves*, Jain Book Depot, 2017.
12. T. S. Bhatti, R. C. Bansal, and D. P. Kothari, *Small Hydro Power Systems*, Dhanpat Rai, 2004.
13. T. Jiandong, Z. Naibo, W. Xianhuan, H. Jing, D. Huishen, *Mini Hydropower*, John Wiley and Sons, 1997.
14. UNIDO, *Small Hydro Power Series*.
15. B. Leyland, *Small Hydroelectric Engineering Practice*, CRC Press, 2014.
16. Websites of the Ministry of Jal Shakthi, Govt. of India, CWC, CEA, NHPC, and NTPC.

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CE6529E WATERSHED MANAGEMENT

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Delineate a watershed
CO2: Assess land use impacts on watersheds
CO3: Model soil erosion
CO4: Plan suitable water harvesting method

Watershed - Definition and delineation, Watershed approach, Hydrologic cycle, Watershed components, Water budget, Watershed assessment, Watershed planning, Watershed as a management unit, Total maximum daily load. Characteristics of watershed - Size, Shape, Physiography, Slope, Climate, Drainage, Land use, Vegetation, Geology and Soils, Hydrology and hydrogeology, Socio-economic characteristics, Basic data on watersheds.

Land use and water quality issues - Land use impacts on watersheds, Residential activities, Municipal sources, Construction, Mining operations, Agriculture, Forestry practices, Recreation. Water quality monitoring – Temperature, pH, Dissolved Oxygen and Biological Oxygen demand, Nutrients, Pathogens, Turbidity, Biological monitoring methods, Species indicators, Biological integrity, Habitat index, Land use index, Water resource assessment, Water yield.

Erosion - Factors affecting erosion, Effects of erosion on land fertility and land capability, Soil Erosion Modelling, Erosivity and erodibility, Processes, USLE and modified/ revised USLE models for erosion processes. Land Management - Survey, Preparation and development, Soil and soil moisture conservation, Conservation measures, Ploughing, Furrowing, Trenching, Bunding, Terracing, Gully control, Rockfill dams, Brushwood dam, Gabion, Rain water management, Reclamation of saline soils.

Water Harvesting: Rainwater harvesting, Catchment harvesting, Harvesting structures, Soil moisture conservation, Check dams, Artificial recharge, Farm ponds, Percolation tanks. Ecosystem management: Role of ecosystem, Crop husbandry, Soil enrichment, Inter, mixed and strip cropping, Cropping pattern, Sustainable agriculture, Bio-mass management, Dry land agriculture, Silvi pasture, Horticulture, Social forestry and afforestation. Model watershed – Government and NGO Projects.

References

1. T. O. Randhir, *Watershed Management: Issues and Approaches*, IWA Publishing, 2006
2. J. V. S. Murty, *Watershed Management*, New Age International, 2013
3. D. K. Majumdar, *Irrigation Water Management*, Prentice Hall, 2014
4. K. N. Brooks, P. F. Folliott, J. A. Magner, *Hydrology and the Management of Watersheds*, Wiley-Blackwell, Fourth edition, 2012
5. E. M. Tideman, *Watershed Management: Guidelines for Indian Conditions*, Omega Scientific Publishers, 1996
6. R. Rajora, *Integrated Watershed Management: Field Manual for Equitable, Productive and Sustainable Development*, Rawat Publications, 2019

CE6530E ENVIRONMENTAL HYDRAULICS

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Model water quality problems in rivers
CO2: Model water quality problems in lakes and estuaries
CO3: Perform hydraulic analysis of water and wastewater treatment plants

Fundamental relationships for flow and transport - general principles, instantaneous equation for fluid flow and transport, Reynold's time-averaged mean flow and transport equations, model resolution, solution techniques, data requirements. Measurement and analysis of flow - measurement of velocity and flow, tracer studies, estimating design flows.

Models for rivers and streams - Completely mixed systems - reaction kinetics, mass balance and steady state solution, particular solutions, feed-forward systems of reactors, feed-back systems of reactors, computer methods. Incompletely mixed systems - diffusion, distributed systems – steady and unsteady cases, steady state solutions, simple time variable solutions. BOD and oxygen saturation, Streeter-Phelps equation, point and distributed sources.

Rivers and streams- stream hydro-geometry, low- flow analysis, dispersion and mixings, flow model complexity and data requirements, estimating mixing in streams and rivers, hydraulic methods for steady and unsteady flows and solution techniques, routing and water quality problems. Mixing in lakes and reservoirs, water balance. Transport and mixing in estuaries.

Hydraulic analysis of various units in water treatment and wastewater treatment plants. Turbulent jets and plumes, ocean wastewater discharge systems.

References

1. S. C. Chapra, *Surface Water Quality Modeling*, Waveland Press, 2008
2. H. Chanson, *Environmental Hydraulics of Open Channel Flows*, Elsevier Butterworth- Heinemann, 2004
3. J. L. Martin and S. C. McCutcheon, *Hydrodynamics and Transport for Water Quality Modeling*, Lewis Pub, 1999
4. H. B. Fischer, E. J. List, R. C. Y. Koh, J. Imberger, and N. H. Brooks, *Mixing in Inland and Coastal Waters,* Academic Press, 1979
5. G. Kiely, *Environmental Engineering*, Tata McGraw Hill Education, 2007
6. F. R. Spellman, *Handbook of Water and Wastewater Treatment Plant Operations*, 3rd ed., CRC Press, 2003
7. S. N. Ghosh, *Tidal Hydraulic Engineering,* Oxford and IBH Pub. Co. Pvt. Ltd, 1998
8. L. D. Benfield, J. F. Judkins, and A. D. Parr, *Treatment Plant Hydraulics for Environmental Engineers*, Prentice Hall, Inc., 1984
9. Z. Ji, *Hydrodynamics and Water Quality*, Wiley, 2017

CE6531E SOFT COMPUTING IN WATER RESOURCES ENGINEERING

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply ANN techniques to solve water resources problems
CO2: Apply fuzzy logic and hybrid systems to solve water resources problems
CO3: Apply genetic algorithms to optimize water resources problems

Soft Computing: Introduction, requirement, different tools and techniques, usefulness and Applications, Support vector Machines (SVM) , Artificial Neural Networks, Biological neural networks, Model of an artificial Neuron, Comparison between biological neuron and artificial neuron, Basic models of artificial neural network, Learning methods, Hebb's learning, Adaline, Perceptron

Back propagation Networks : Architecture - Multi layer perceptron –Back propagation learning – Input layer, Hidden Layer , Output Layer computations, Calculation of error, Training of ANN, Back propagation Algorithm, Momentum and Learning rate, Selection of various parameters in BP networks- Radial Basis Function Networks, Applications of ANN in Water Resources Engineering

Fuzzy sets and fuzzy logic, Fuzzy sets and crisp sets, Fuzzy set operations, Fuzzy relations, Membership functions, Features of the membership functions, Fuzzification, Defuzzification, Defuzzification methods, Fuzzy Rule Base and approximate reasoning, Formation of rules, Decomposition of rules, Fuzzy Inference Systems, Construction and Working Principle of FIS, Methods of FIS, Mamdani FIS and Sugeno FIS, Application of FLC Systems in Water Resources Engineering

Genetic Algorithms, Basic Concepts, Creation of off springs, Working Principle, Encoding, Fitness function, Reproduction, Roulette Wheel Selection, Boltzmann Selection, Tournament selection, Rank Selection, Steady State Selection, Elitism, operators in GA, Cross Over, Inversion and deletion, Mutation Operator, Bit wise operators, Convergence of Genetic Algorithm, Stopping Condition, Constraints in GA, Classification of GA, Advances in GA, ,Genetic Programming, Applications of GA in Water Resources Engineering.

Hybrid Soft Computing Techniques, Neuro Fuzzy Hybrid Systems, Genetic Neuro Hybrid systems, Genetic fuzzy Hybrid and fuzzy genetic hybrid systems, Hybrid systems applications in Water Resources Engineering.

References

1. F. Karray and C. De Silva, *Soft Computing and Intelligent Systems Design: Theory, Tools and Application*, Pearson Education, 2004
2. S. Sivanandam and S. Deepa, *Principles of Soft Computing*. Wiley India Pvt Ltd, New Delhi: 2013
3. D. E. Goldberg, *Genetic Algorithms*. Pearson Education India, 2006
4. S. Haykin, *Neural Networks and Learning Machines*. Upper Saddle River: Prentice Hall, 2009
5. H. Zimmermann, *Fuzzy Set Theory and its Applications*. Boston: Kluwer Academic, 2014
6. T. Ross, *Fuzzy Logic with Engineering Applications*, 3rd ed. Wiley India, 2009
7. S. Rajasekaran and G. A Vijayalakshmi Pai, *Neural Networks, Fuzzy Logic, and Genetic Algorithms - Synthesis and Applications*, Prentice Hall of India, New Delhi: 2017

CE6532E URBAN HYDROLOGY AND DRAINAGE

L	T	P	O	C
3	0	0	6	3

Prerequisites: CE6502E Surface Water Hydrology and Hydrologic Systems

Total Lecture Sessions: 39

Course Outcomes:

CO1: Perform rainfall and runoff computations for urban catchments
CO2: Compute overland flow and channel flows
CO3: Design stormwater drainage systems

Rainfall and Runoff Computations
Introduction - Urbanization –Stormwater runoff quantity and quality issues – Rainfall design for urban catchments – Hydrologic and probabilistic description of rainfall – Design rainfall – Methods for construction of design storm hyetographs – Rainfall excess calculations – Computation of abstractions –Combined loss models
Calculation of runoff rates-basic concepts – elements of urban runoff hydrographs – Time of Concentration – Definition and calculation by various methods – Unit hydrograph method – NRCS method (TR-55)

Channel flow and Overland flow
Open-channel flow – Definitions - States of open channel flows – Open - Channel flow equations – Steady Gradually varied flow – Normal flow – Open channel rating curve – Overland flow – Kinematic wave model – Overland flow on impervious and pervious surfaces – Channel flow routing– simplified and numerical models

Storm Water Drainage
Design of stormwater drainage structures –Drainage design for street pavements – Storm sewer systems – Culverts – Surface drainage channels

Storm Water Management
Urban flooding and associated issues – Detention basins – Stage-storage relationship, Stage-discharge relationship - Detention basin design
Infiltration practices - Infiltration basins, Trenches, Dry wells, Porous pavements
Urban stormwater pollution – Modelling stormwater quality – Annual pollutant load estimates
Strom water quality control - Concepts of BMPs– Extended detention basins – Retention basins – Water quality trenches –Sand filters – Stormwater wetlands – vegetative BMPs
Low Impact Development - Advantages – Urban stormwater computer models – HEC-HMS – EPA-SWMM

References
1. O. Akan, A and R. J. Houghtalen, *Urban Hydrology, Hydraulics, and Stormwater Quality: Engineering Applications and Computer Modeling*, John Wiley and Sons, First edition, 2013
2. V. T. Chow, D. Maidment, and L. W. Mays, *Applied Hydrology*, McGraw Hill Co. First edition, 2017
3. D. Butler, C. Digman, C. Makropoulos and J. W. Davies, *Urban Drainage*, CRC Press, Fourth edition, 2018
4. H. Pazwash, *Urban Storm Water Management*, CRC Press, Second edition, 2016
5. *National Engineering Handbook*, Part 630, Natural Resources Conservation Service, United States Department of Agriculture
6. *HEC-HMS Technical Reference Manual*, US Army Corps of Engineers, CPD-74B
7. *Storm Water Management Model Applications Manual*, USEPA - EPA/600/R-09/077

CE6533E COASTAL ENGINEERING AND COASTAL ZONE MANAGEMENT

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Estimate wave forces on structures and design these structures
CO2: Estimate littoral transport and coastal erosion
CO3: Plan, design, and execute structural and non structural coastal protection measures

Coastal Engineering – coastal environment and coastal zone, problems, water level fluctuations – tides, surges and seiches. Introduction to wave mechanics – wave generation, small amplitude wave theory - formulation and solution, wave celerity, length and period, classification of waves based on relative depth, orbital motions and pressure, standing waves, wave train and wave energy. Wave transformation – shoaling, reflection, refraction and diffraction, Breaking of waves.

Finite Amplitude Waves – higher order wave theories such as Stokes wave theory, Cnoidal wave theory, trochoidal wave theory, solitary wave theory, and stream function wave theory. Numerical wave theory. Wave interaction with currents. Regimes of application of different wave theories. Tsunamis.

Short term and long term wave statistics. Sea as a stationary random process - wave spectral density, mathematical spectrum models. Wind generated waves – wave forecasting and wave hindcasting.

Wave structure interaction – Forces on shore structures due to breaking, broken and nonbreaking waves. Design of rubble mound structures. Wave force on a circular (vertical, inclined and oscillating cylinder) - Morison Equation, wave force on submarine pipelines.

Coastal processes - long term and short term changes in the shoreline, cross shore and long shore currents, onshore-offshore movement of sediments, longshore transport, application of mathematical models, factors affecting equilibrium of beaches. Causes of coastal erosion. Shore protection. Type of beaches. Methods of shore protection – structural and nonstructural methods. Coastal erosion and protection along the Kerala coast. Integrated coastal zone management - resource planning and management, goals and purposes, sustainable use of resources, Application of IT. Coastal ecosystems including mangroves. Mudbanks. Legislation in India pertaining to the coastal zone.

References

1. A. T. Ippen (ed.), *Estuary and Coastline Hydrodynamics*, McGraw Hill, Inc., 1966
2. R. M. Sorenson, *Basic Coastal Engineering,* 3rd ed., Springer Verlag, 2006
3. US Army Corps of Engineers, *Coastal Engineering Manual – Parts I to VI*
4. T. Sarpkaya and M. Isaacson, *Mechanics of Wave Forces on Offshore Structures*, Van Nostrand., 1981
5. D. Reeve, A. Chadwick, and C. Fleming, *Coastal Engineering: Processes, Theory, and Design Practice*, 3rd ed., CRC Press, 2018
6. J. S. Mani, *Coastal Hydrodynamics*, PHI Learning, 2011
7. V. Sundar, *Ocean Wave Mechanics: Applications in Marine Structures, Ane Books, 2016*
8. R. G. Dean and R. A. Dalrymple, *Coastal Processes with Engineering Applications*, Cambridge University Press, 2004
9. J. W. Kamphius, *Introduction to Coastal Engineering and Management*, World Scientific, 2010

CE6534E POLLUTION SCIENCE AND ENGINEERING

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Carryout environmental monitoring and risk assessment
CO2: Model processes affecting the fate and transport of contaminants in the environment
CO3: Apply scientific techniques for waste disposal and management

Major environmental issues of the 21st century. The extent of global pollution. The environment as a continuum, Overview of environmental characterization. Ecological concepts and natural resources. Brief introduction to chemistry and microbiology in pollution science. Physical and chemical characteristics of soil, water, and the atmosphere, biotic characteristics of the environment.

Physical, chemical, and biological processes affecting fate and transport of contaminants in soil and water. Physical, chemical and biological contaminants. Environmental monitoring. Brief introduction to environmental toxicology. Statistics in pollution science. Risk assessment. Environmental laws and regulations in India.

Pollution and mitigation of pollution of soil and land, and ground and surface waters. Fertilizers, pesticides and sediments as a source of pollution. Atmospheric Pollution. Global atmospheric changes. Introduction to global warming and climate change.

Solid waste treatment and disposal, municipal wastewater treatment, land application of biosolids and animal wastes. Drinking water treatment and water security. Environmental Management.

References

1. I. L. Pepper, C. P. Gerba, and M. L. Brusseau, *Environmental and Pollution Science*, 2nd ed., Academic Press, 2011
2. G. M. Masters, and W.P. Ela, *Introduction to Environmental Engineering and Science*, 3rd ed., PHI Learning, 2008
3. M. Davis, and S. Masten, *Principles of Environmental Engineering & Science*, 3rd ed., McGraw-Hill Higher Education, 2013
4. G. Kiely, *Environmental Engineering*, Tata McGraw Hill Education, 2007
5. F. R. Spellman, *Handbook of Water and Wastewater Treatment Plant Operations*, 3rd ed., CRC Press, 2003
6. J. G. Henry and G. W. Heinke, *Environmental Science and Engineering*, Pearson Education, 1996
7. W. P. Cunningham and M. A. Cunningham, *Environmental Science – A Global Concern*, 13th ed., McGraw Higher Ed., 2015

CE6535E HYDROCLIMATOLOGY

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:
CO1: Select climate variables affecting precipitation at a location
CO2: Perform risk assessment and mapping with respect to extreme events
CO3: Extract GCM projections and downscale these for a river basin
CO4: Perform hydrological impact assessment of projected climate change

Introduction to hydro-climatology: climate system; climate, weather and climate; overview of earth's atmosphere; vertical structure of atmosphere; radiation and temperature; laws of radiation; heat-balance of earth atmosphere system; random temperature variation; modeling vertical variation in air temperature; temporal variation of air temperature; temperature change in soil; thermal time and temperature extremes.

Hydrologic cycle: introduction; global water balance; cycling of water on land, a simple water balance model; climate variables affecting precipitation, precipitation and weather, humidity, vapor pressure, forms of precipitation, types of precipitation; cloud; atmospheric stability; monsoon; wind pattern in India; global wind circulation; Indian summer monsoon rainfall.

Climate variability: floods, droughts, drought indicators, heat waves, climate extremes. steps of risk characterization - hazard identification, exposure assessment, vulnerability analysis, risk mapping, risk characterization to natural hazards, risk assessment as a distributed process.

Climate change: introduction; causes of climate change; modeling of climate change, global climate models, general circulation models, downscaling; IPCC scenarios; commonly used statistical methods in hydro-climatology: trend analysis; empirical orthogonal functions, principal component analysis; canonical correlation; statistical downscaling with regression.

References
1. G. S. Campbell, and J. M. Norman, *An Introduction to Environmental Biophysics*, Springer, 2013
2. W. M. Washington, and C. L. Parkinson, *An Introduction to Three Dimensional Climate Modeling*, Oxford University Press, 2005
3. M. L. Shelton, *Hydroclimatology: Perspectives and Applications*, Cambridge University Press, 2009
4. K. McGuffie, and A. Henderson-Sellers, *The Climate Modelling Primer* 4th edition, Wiley Blackwell, 2014
5. *Reports of the IPCC and the Indian National Committee on Climate Change*

CE6536E DISASTER MANAGEMENT

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:
CO1: Assess the hazards and risks involved in various types of disaster
CO2: Apply ICT and geoinformatics in disaster management
CO3: Apply disaster mitigation strategies following the national initiatives and framework

Disaster, Hazard, Vulnerability, Resilience, Risks. Natural disasters - hydro-meteorological disasters such as flood, flash flood, cloud burst, drought, cyclone, forest fires etc; geological disasters like earthquake, tsunami, landslides, volcanic eruption. Man made disasters - chemical industrial hazards, major power break downs, traffic accidents, fire hazards, biological hazards, nuclear accidents. Environmental hazards - forest hazards (deforestation, degradation and forest fire), land and soil degradation, desertification and pollution (water, air and soil).Disasters and national losses. Historical perspective of disasters in India and the Indian sub continent.Recent major disasters. Disaster management cycle and its components. Earthquake, Landslide, Flood, Drought, Fire etc - classification, causes, impacts including social, economic, political, environmental, health, psychosocial, etc.- Differential impacts - in terms of caste, class, gender, age, location, disability - Global trends in disasters: urban disasters, pandemics, complex emergencies, Global warming and climate change. Adaptation.Dos and don’ts during various types of disasters.

Disaster cycle - Phases, Culture of safety, prevention, mitigation and preparedness, community based DRR, structural and nonstructural measures, roles and responsibilities of the community, Panchayati Raj institutions/ Urban Local Bodies, States, Centre, and other stakeholders including NGOs. Institutional processes and framework at State and Central Level – National and State Disaster Management Authorities. Prediction and early warning systems. Role of information, education, communication, and training, geoinformatics and IT in disaster preparedness, risk assessment, response, recovery, and management. Role of engineers on disaster management.

Components of disaster relief - water, food, sanitation, shelter, health, waste management, Institutional arrangements for mitigation, response and preparedness, Legislation in India on Disaster Management. National disaster management policy. Other related policies, plans, programmes and legislation relevant to/ pertaining to disaster management. Disaster damage assessment. Disaster mitigation. Existing organizational structure for managing disasters in India. Case studies.

References
1. S. R. Sharma, *Disaster Management*, A P H Publishers, 2011
2. S. S. Nair, *Training Manual on Geoinformatics Applications in Disaster Management*, NIDM, 2012
3. H. K. Gupta, *Disaster Management*, Universities Press, 2003
4. J. P. Singhal, *Disaster Management*, Laxmi Publications, 2010
5. K. V. Rao, *Geoinformatics for Disaster Management*, Manglam Publishers and Distributors, 2010
6. J. A. Matthews, *Natural Hazards and Environmental Change*, Bill McGuire, Ian Mason, 2002
7. M. M. Sulphey, *Disaster Management*, PHI Learning, 2016
8. D. P. Coppola, *Introduction to International Disaster Management*, Butterworth-Heinemann, 2016.
9. P. Diwan, *A Manual on Disaster Management*, Pentagon Press, 2010
10. Websites of the National Disaster Management Authority, National Institute for Disaster Management, and State Disaster Management Authorities

CE6537E ENVIRONMENTAL FLOWS

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Identify the issues related to environmental flow in rivers
CO2: Model processes affecting the fate and transport of contaminants in the environment
CO3: Perform realistic assessment of environmental flows and monitoring in the field

Fundamental concept of environmental flow – catchment drainage network and resource regimes – river ecology, the natural flow regime paradigm and hydro ecological principles – reservoir and dam Planning – institutionalising environmental flow through adaptive reservoir operations – defining environmental water status - effects of catchment change and river corridor engineering

River morphology – Meandering of rivers – Control Volume – Mass balance and advective/ dispersive transport – transport in rivers, lakes, wetlands, and estuaries - sediment transport. Paleolimnology

Stream-aquifer interaction - quality of water – factors effecting water quality - control volume – Mass balance and advective / dispersive transport - groundwater aquifers, Darcy's Law and flow nets – Transient well hydraulics, Transport and retardation – Flow in the unsaturated zone, Biodegradation and bioremediation – Gaussian plume modelling

Environmental flow assessment methods – Hydraulic rating and habitat simulation methods – Flow protection methods – flow restoration methods – ecological limits of hydraulic alteration (ELOHA) – environmental flow relationships, models and applications – setting limits to hydrologic alteration – Implementing and monitoring environmental flow – NatCap (Natural Capital Project) – InVest Software tool for mapping, modelling and visualising ecosystem services - eWater toolkit – IHA (Indicators of Hydrologic Alterations)

References

1. A. H. Arthington, *Environmental Flows: Saving Rivers in the Third Millennium*, Univ of California Press, 2012
2. K. A. Fryirs and G. J. Brierley, *Geomorphic Analysis of River Systems*, Wiley-Blackwell, 2013
3. N. D. Gordon, T. A. McMahon, and B. L. Finlayson, *Stream Hydrology: An Introduction for Ecologists*, John Wiley and Sons, 2004
4. A. J. Schleiss and R. M. Boes (eds.), *Dams and Reservoirs under Changing Challenges*, CRC Press, 2011
5. W. Lick, *Sediment and Contaminant Transport in Surface Waters*, CRC Press, 2009
6. J. S. Gulliver, *Introduction to Chemical Transport in the Environment*, Cambridge University Press, 2007

CE6538E DAM SAFETY

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Identify the causes and modes of failure of various types of dams
CO2: Perform inspection and assessment of safety of dams
CO3: Plan and implement an appropriate scheme for instrumentation of dams

Dams - Types & Classification. Considerations governing choice of the type of dam. Design considerations. Dam failures - history of dam failures in India and abroad. Failure of dams - causes of failures of different types of dams – hydrological, structural, non-structural. Geophysical and other investigations for assessment of structural health of dams. Hydrological assessment of dam safety. Remedial and rehabilitation action for safety of dams - structural & non-structural measures. Dam break analysis. Emergency Action Plan - 1D/2D- various tools- input requirements - inundation maps.

Dam safety inspection - routine-pre-monsoon/post-monsoon comprehensive inspections. Guidelines for dam safety inspection. Role of Central Water Commission. International guidelines –USBR, FEMA, USACE. Need of proper O&M for dams.

Safety evaluation of dams - need of safety evaluation - risk analyses and risk assessment - portfolio risk analyses - techniques & methods in risk analyses and safety evaluation for decision making. Role of Dam Safety Organisations and Dam Safety Review Panels. Legislation for Dam Safety.

Instrumentation in dams - objectives of monitoring dam performance, types of measurements, installation of instruments, frequency of measurement, technical specification of various instruments employed, seismic instrumentation, performance evaluation through instrumentation, automated data acquisition, real time structutal health monitoring, real time data acquisition and early warning system for floods.

References

1. W. P. Creager, J. D. Justin, J. Hinds, *Engineering for Dams, Vols. I, II, and III, Wiley*, 1945
2. M. M. Dandekar and K. N. Sharma, *Water Power Engineering*, Vikas Publishing House (P) Ltd., 2015
3. P. Novak, A. I. B. Moffat, C. Nalluri and R. Narayanan, *Hydraulic Structures*, 4th ed., Taylor and Francis, 2007
4. R. S. Varshney, *Concrete Dams*, Oxford and IBH, 1982
5. H. D. Sharma, *Concrete Dams*, CBIP, 1998
6. L. Zhang, M. Peng, D. Chang, and Y. Tsu, *Dam Failure Mechanisms and Risk Assessment*, Wiley, 2016
7. *Guidelines Pertaining to Dam Safety* of the CWC, FEMA, USBR
8. Website of the Central Water Commission (CWC), and the Dam Rehabilitation and Improvement Project (DRIP)