Proposal

for

Master of Technology Programme

in

Water Resources Engineering and Climate Change

Civil Engineering Department

Motilal Nehru National Institute of Technology

Allahabad-211004

MOTILAL NEHRU NATIONAL INSTITUTE OF TECHNOLOGY

ALLAHABAD

SCHEME OF INSTRUCTION AND SYLLABI

for M. Tech. Program in Water Resources Engineering and Climate Change

DEPARTMENT OF CIVIL ENGINEERING

Vision and Mission of the Institute

Motilal Nehru National Institute of Technology Allahabad

VISION

- To attain a distinct identity for the Institute through technology innovation, knowledge creation and dissemination for the benefit of the society

MISSSION

- To nurture an ecosystem for continuous enhancement of value-based teaching and learning process in the emerging areas of technology.
- To train quality human and knowledge resources in the service of society
- To develop sustainable products and technologies

Vision and Mission of the Department

Department of Civil Engineering

VISION

- The Department of Civil Engineering is committed towards the excellence in education, research, and professional development of the students, faculty members, and staff to enable them to productively contribute towards the sustainable development and advancement of our country.

MISSSION

- Mission 1 (M1): To educate students who will employ their knowledge, skill and innovation to excel as Civil Engineers and contribute fruitfully towards the development of our country.
- Mission 2 (M2): To carry out productive research to discover and develop new knowledge and sustainable technologies that improve the practice of engineering in service to society.
- Mission 3 (M3): To serve and improve the Institute, the Civil Engineering Profession, and society at large.

Department of Civil Engineering:

Brief about the Department:

The Civil Engineering Department offers a Bachelor of Technology and four regular post graduate courses in Structural, Environmental, Transportation and Geotechnical Engineering. It also offers a highly sought after part-time course for in-service engineers in Computer Aided Design in Civil Engineering. The Department is also a recognized QIP (Quality Improvement Program) Centre for post graduate studies. The course curriculum is up to date, spanning disciplines that cover both traditional concepts and recent developments. A strong foundation is laid through courses on Concrete and Steel Structures, Geotechnical Engineering, Environmental Engineering, Transportation Engineering, Irrigation Engineering and Computer Application. Besides, students are offered a variety of electives dealing with subjects like Advance Engineering, Properties of Soil, Computer Simulation, Rock Mechanics, Ecology and Operations Research. The theoretical courses are supplemented by imparting practical experience through well-equipped laboratories.

The Civil Engineering Department, apart from Teaching and R&D, also does an enormous amount of consultancy, which adds up to the institutional internal revenue generation and involves faculty and students in challenging field problems. There are four centers of excellence in the Department, and most laboratories have state-of-the-art equipment.

The faculty of the Department are actively involved in sponsored projects and have prestigious projects like SPARC, BRICS, IMPRINT, DST, SERB, DBT, ARDB, to name a few. The Department takes pride in having conducted the highest number of GIAN and SPARC programs.

Department of Civil Engineering

M.Tech. (Civil): *Water Resources Engineering and Climate Change*

Water resources engineering is the study and management of equipment, facilities and techniques that are used to manage and preserve life's most plentiful resource. In addition to assessing how and the best ways in which to manage and control water as it pertains to water-related activities – such as irrigation, water supply, canal development and hydrologic extremes due to changing climate. Water resource engineers are also frequently involved in water management. Climate change is a critical challenge for the overall development of any country. India, with its vast and varied geography, is particularly vulnerable to the impacts of climate change, including increased frequency and intensity of extreme weather events like floods and droughts. Understanding and addressing these impacts is essential for sustainable development. The development of M. Tech courses in **"*Water Resources Engineering and Climate Change*"** will equip students with the knowledge and skills needed to understand the water related problems, climate change challenges in water resources, and to mitigate and adapt to these challenges. Dams and other water management infrastructure play a crucial role in providing water, flood control, recreation, and economic opportunities. However, in the context of climate change, the safe operation and maintenance of these structures are more important than ever to sustain their benefits and prevent potential disasters due to failure. The study of hydrology and hydraulics, especially in relation to climate change, is central to the development of sustainable water resource management strategies. The curriculum of the PG programme in **"*Water Resources Engineering and Climate Change*"** is designed with a focus on understanding the changing patterns of water availability and the design of projects that can adapt to these changes, ensuring the resilience and sustainability of water resources for future generations.

The proposed Master of Technology degree programme in Civil Engineering in **"*Water Resources Engineering and Climate Change"*** has objective of broadening the perspective to persons in the water resources related fields of Civil Engineering encompassing academic institutes, research organizations, public sectors, and consulting for original, creative, and independent thinking. For some jobs, a Masters or Doctoral degree is required or considered desirable for professional development. In addition, the research component of the PG programme in **"*Water Resources Engineering and Climate Change"*** is meant to develop capabilities to confidently undertake independent analysis of complex field situations. The MNNIT graduates have gone on to become leaders in their profession and have made significant contributions to research and development. Keeping in view the needs of the society and the challenging problems faced by the profession, postgraduate programme is proposed in **"*Water Resources Engineering and Climate Change"***. The program has sufficient breadth to accommodate both those students who wish to emphasize preparation for professional practice as well as those who wish to orient their studies towards a research or academic career.

ELIGIBILITY REQUIREMENTS

Four-year Bachelor's degree or five-year integrated degree in Civil/ Agricultural/ Infrastructure/ Environmental/ Geomatics Engineering, with 60% or CPI of 6.0 (on 10.0 scale) in the qualifying degree as per the prevailing norms of MNNIT, Allahabad. A Valid GATE qualification in Civil Engineering (CE)/ Agricultural Engineering (AG)/ Environmental Science and Engineering (ES)/ Geomatics Engineering (GE) is required. *Relaxation as per GoI norms in qualifying degree is applicable for SC and ST category applicants.*

The number of seats in the M.Tech programme: 25 (Regular)

M.Tech. (Civil) – *Water Resources Engineering and Climate Change*

FIRST SEMESTER (FULL-TIME)

Course No.	Subject	Scheme of periods per week			Total Credits
		L	T	P	
CE21141	Advanced Hydrology	3	1	-	4
CE21142	Climate Change and Sustainability	3	1	-	4
CE21XXX	Elective I	3	1	-	4
CE21XXX	Elective II	3	1	-	4
CE21XXX	Elective III	3	1	-	4
	Total				**20**

SECOND SEMESTER (FULL-TIME)

Course No.	Subject	Scheme of periods per week			Total Credits
		L	T	P	
CE22141	River Engineering and Flood Control	3	1	-	4
CE22142	Water Resources Engineering and Climate Lab	-	-	6	4
CE22XXX	Elective IV	3	1	-	4
CE22XXX	Elective V	3	1	-	4
CE22XXX	Elective VI	3	1	-	4
CE22XXX	Technical Field Visit/Industrial Visit	S/X			
	Total				**20**

THIRD SEMESTER (FULL-TIME)

Course No.	Subject	Credits
CE23671	Special Study / Industrial Training / Colloquium/Term Paper	4
CE23621	Thesis	16
	Total	**20**

FOURTH SEMESTER (FULL-TIME)

Course No.	Subject	Credits
CE24621	Thesis	20
	Total	**20**

List of Electives Odd Semester

Elective-I

S. N.	Subject Code	Name of the Subject
1	CE21XXX	Free Surface Flows
2	CE21XXX	Hydraulics of Sediment Transport
3	CE21XXX	Advanced Fluid Mechanics
4	CE21XXX	Computational Fluid Dynamics
5	CE21XXX	Water Resources Systems Planning and Management

Elective-II

S. N.	Subject Code	Name of the Subject
1	CE21XXX	Groundwater Hydrology
2	CE21XXX	Stochastic Hydrology
3	CE21XXX	Watershed Modelling
4	CE21XXX	Urban Hydrology and Drainage
5	CE21XXX	Glaciology

Elective-III

S. N.	Subject Code	Name of the Subject
1	CE21XXX	Fluid – Structure Interaction
2	CE21360	Numerical Computation and Simulation
3	CE21XXX	Computational Methods in Water Resources Engineering
4	CE21357	Soft Computing Methods in Engineering Problem Solving
5	CE21359	Aritificial Intelligence for Remotely Sensed Image Processing and GIS

List of Electives Even Semester

Elective-IV

S. N.	Subject Code	Name of the Subject
1	CE21XXX	Climate and Climate Change Modelling
2	CE21XXX	Climate Change and its impact on Water Resources
3	CE21XXX	Climate Variability and Global Warming
4	CE21XXX	Climate Change Vulnerability and Mitigation
5	CE21XXX	Coastal Processes and Climate Change

Elective-V

S. N.	Subject Code	Name of the Subject
1	CE21XXX	Design of Hydraulic Structures
2	CE21XXX	Hydropower Engineering
3	CE21XXX	Dams and Reservoirs
4	CE21XXX	Irrigation and Drainage Works
5	CE21XXX	Hydrometeorology

Elective-VI

S. N.	Subject Code	Name of the Subject
1	CE22358	Environmental Impact Assessment
2	CE22301	Optimization Methods in Civil Engineering
3	CE22357	Groundwater Contamination and Pollution Transport
4	CE21XXX	Hydrogeology
5	CE21XXX	Oceanography

COURSE-CURRICULUM

CORE COURSES
SEMESTER I (ODD)

Course code: CE21141	**Advanced Hydrology**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand the hydrologic cycle and its role in engineering and eco-hydrology.
CO2	Analyze and evaluate precipitation and its abstracts' characteristics
CO3	Apply hydrograph theory to construct hydrographs and runoff models.
CO4	Evaluate flood flows and create flood hydrographs by flood routing
CO5	Design hydrologic systems for flood forecasting, control and management.

Course Contents:

Unit 1: Introduction: Description of hydrologic cycle, overview of application of hydrology in engineering, historical aspects of development of hydrology, eco-hydrology hydrologic system and hydrologic budget, fundamental laws of hydrology; atmospheric water vapor. **(8L)**

Unit 2: Precipitation: Characteristics of precipitation in India, Measurement of precipitation, rain gauge network, intensity duration-frequency analysis and depth-area-duration analysis, Abstractions: Evaporation and Evapotranspiration, measurement, Estimation and control of evaporation, Infiltration process, measurement. **(7L)**

Unit 3: Hydrograph Theory: Runoff characteristics, flow duration curve and flow mass curve Components of hydrograph, direct runoff hydrograph, unit hydrograph theory, S-hydrograph and instantaneous unit hydrograph, conceptual models - synthetic unit hydrograph and its derivation. **(7L)**

Unit 4: Floods and routing: Flood forecasting – empirical relations, flood frequency analysis, reliability analysis, basic equations for routing, hydrologic and hydraulic routing, conceptual hydrograph for routing, Nash and Clark's methods, probabilistic treatment of hydrologic data, probability distributions for hydrologic variables. **(10L)**

Unit 5: Hydrologic Statistics and Design: Design scale, uncertainty analysis, design precipitation depth, probable maximum precipitation, design flows, peak flows, flood forecasting, flood control reservoir design. **(8L)**

References:

1. Chow, V.T., Maidment, D.R. and Mays, W.L., "Applied Hydrology", 1988.
2. Ojha, C.S.P., Berndtsson, R. and Bhunya, P., "Engineering Hydrology", Oxford University Press, 2008.
3. Wanielista, M., Kersten, R. and Eaglin, R., "Hydrology", John Wiley, 1997.
4. Engineering Hydrology, Subramanya, K and Sharma,P.K, Tata McGraw Hill Publications, 2024 6th Edition
5. Hydrologic Analysis and Design, McCuen, R.H., Pearson Publications, 2017 4th Edition

Course code: CE21142	**Climate Change and Sustainability**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand climate change, forcing mechanism, IPCC scenarios and the role of ecosystem services in water availability.
CO2	Evaluate the performance of GCMs and apply downscaling techniques and bias corrections for climate modelling.
CO3	Understand the water-climate-energy nexus and apply statistical and optimization techniques for drought management.
CO4	Apply statistical optimization and modelling techniques for drought management and climate change impacts.
CO5	Create strategies for sustainability and resilience of water resources systems

Course Contents:

Unit 1: Introduction, climate change and variability, forcing mechanisms, IPCC climate scenarios, impact of climate change, review of climate change aspects, introduction to ecosystem services, importance of water availability for crop water production. **(8L)**

Unit 2: Global Climate Models: Introduction, performance indicators for evaluating GCMs, ranking of GCMs, downscaling techniques in climate modeling: statistical downscaling, multisite downscaling, nested bias correction. **(7L)**

Unit 3: Water – Climate Models: Water- climate-energy nexus, importance of groundwater management, Drought-types and index used statistical and optimization techniques in climate modeling, data compression techniques, trend detection techniques and optimization methods. **(7L)**

Unit 4: Hydrological Modeling: Introduction, storm water management model, hydrologic engineering center-hydrologic modeling system, soil and water assessment tool and other modelling techniques, case studies of hydrologic impact of climate change. **(7L)**

Unit 5: Sustainability: Significance and roles of sustainability, sustainability of river and ground water resources, resilience of hydrologic systems, simulation and modeling through case studies, socio- economic consideration. review of water policies, Framework of water policies in consideration of supply and demand. **(8L)**

References:

1. S. Shrestha, M. S. Babel and V. P. Pandey, (2014). Climate Change and Water Resources, CRC Press, Taylor and Francis Group, Boca Raton.
2. Rao Y Surampalli, Tian C Zhang, Manish Kumar Goyal, Satinder K Brar, RD Tyagi, (2020). Sustainability: Fundamentals and applications, John Wiley & Sons, Volume 1, -ISBN: 978-1-119-43396-5
3. E. Kolokytha, Soishi and R. S.V. Teegavarapu, (2016). Sustainable Water Resources Planning and Management Under Climate Change, Springer, Heidelberg, 978-9811020513
4. Houghton, J. (2009). *Global warming: the complete briefing*. Cambridge university press.
5. Edenhofer, O. (Ed.). (2015). *Climate change 2014: mitigation of climate change* (Vol. 3). Cambridge University Press.
6. IPCC Sixth Assessment Report (2021).
7. Raju, K. S., & Kumar, D. N. (2018). Impact of Climate Change on Water Resources.

CORE COURSES
SEMESTER II (EVEN)

Course code: CE22141	River Engineering and Flood Control	Credits 3 - 1 - 0: 4

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand the characteristics of river channels.
CO2	Understand and analyze river equilibrium, particle stability, and river meandering.
CO3	Understand and analyze classification of flows and sediment transport processes.
CO4	Analyze and evaluate river dynamics, stabilization methods, and protection.
CO5	Create flood control strategies using structural and non-structural measures.

Course Contents:

Unit 1: Introduction: Generalized and local characteristics of river channels, change in principal hydrological characteristics, stability of the channel and rate of the channel process. **(8L)**

Unit 2: River equilibrium: Particle stability, channel stability, regime relationships, equilibrium in river bends, downstream hydraulic geometry, bars in alluvial rivers, river meandering, lateral river migration. **(7L)**

Unit 3: Classification of river flows: Steady, unsteady, uniform and non-uniform flow in rivers, sediment transport in rivers, river continuity equation, river momentum equations, river flood waves, loop-rating curves, river flow and sediment-duration curves. **(7L)**

Unit 4: River Dynamics and Stabilization: riverbed aggradation and degradation, river stabilization, riverbank stability, riverbank riprap revetment, river flow-control structures, and dredging. **(7L)**

Unit 5: Flood Control: Flood forecasting, flood damage mitigation, structural and non-structural methods, mathematical river models, finite-difference approximations, one-dimensional river models, multidimensional river models. **(8L)**

References:

1. Chang, H. H. (2004). Fluvial Processes in River Engineering. Wiley.
2. Julien, P. Y. (2002). River Mechanics. Cambridge University Press.
3. Petersen, M. S. (2005). River Engineering. McGraw-Hill.

4.Thorne, C. R., Hey, R. D., & Newson, M. D. (Eds.). (1997). Applied Fluvial Geomorphology for River Engineering and Management. John Wiley & Sons.
5. Yalin, M. S. (2015). River Mechanics (2nd ed.). Elsevier.
6. Stevenson, D. (2013). The Principles and Practice of Canal and River Engineering. Cambridge University Press.
7. Ghosh, S. N. (1997). Flood Control and Drainage Engineering (4th ed.). CRC Press.
8. Di Baldassarre, G. (2012). Floods in a Changing Climate: Inundation Modelling. Cambridge University Press.
9. Szollosi-Nagy, A., & Zevenbergen, C. (Eds.). (2004). Urban Flood Management: Introduction - 1st International Expert Meeting on Urban Flood Management. CRC Press.
10. Sayers, P. (Ed.). (2012). Flood Risk: Planning, Design and Management of Flood Defence Infrastructure. ICE Publishing.

Course code: CE22142	**Water Resources Engineering and Climate Lab**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE
Course Outcomes: At the end of the course, the student will be able to

CO1	Understand flow hydrodynamics under scenarios of raised crest, broad-crested weir and bed with vegetation
CO2	Investigate the sediment transport processes.
CO3	Create hydrologic watersheds and analyze land use/land cover (LULC) changes.
CO4	Apply general circulation climate models to project future hydro-climatic variables.
CO5	Design hydrologic and hydraulic models

List of experiments:
Students will perform any five experiments given below.

1. To examine energy loss in a hydraulic jump.
2. To measure flow over a broad-crested weir.
3. To investigate flow over vegetation.
4. To observe incipient motion of a sediment particle.
5. To delineate hydrologic watershed and perform LULC analysis.
6. Application of general circulation climate model for future projections of hydro climatic variables.
7. Application of hydrologic models using climatic data in HEC-HMS
8. Development of hydrologic models using climatic data in Arc-SWAT.
9. Development of hydraulic models for flood mapping using HEC-RAS/SFINCS.

References:

1. Deka, P.C., Bekele, N., Abete, B.Z. (2011). GIS based HEC-HMS and HEC-RAS modeling. Lambert Academic Publishing.
2. Hydrologic Engineering Centre (U.S)-The Hydrologic Modeling System (HEC-HMS) Technical Reference Manual.
3. Hong, K.A., and Hong, J.L. (2020) River Routing Using HEC-HMS. Lambert Academic Publishing.
4. Chin, D. A., Mujumdar, A., & Roy, P. K. (2000). Water-resources engineering (Vol. 12). Englewood Cliffs: Prentice Hall.
5. Chaudhry, H. (2008). Open Channel Flow, Springer.
6. R.J. Garde (2000). Mechanics of Sediment Transportation and Alluvial Stream Problems, New Age International Publishers.
7. Anderson, J. D., & Wendt, J. (1995). *Computational fluid dynamics* (Vol. 206). New York: McGraw-Hill.

ELECTIVE COURSES
SEMESTER I (ODD)

ELECTIVE-I

Course code: CE21XXX	Free Surface Flows	Credits 3 - 1 - 0: 4

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand the concepts of free surface flow, and the application of mass, momentum and energy equations.
CO2	Analyze uniform flow and flow resistance.
CO3	Analyze gradually varied flow and spatially varied flow profiles.
CO4	Understand the characteristics of rapidly varied flows.
CO5	Apply the principles of unsteady flow and flow wave dynamics.

Course Contents:

Unit 1: Introduction: Review of free surface flow concepts including velocity and pressure distribution, continuity, momentum and energy equation, concept of specific energy, computation of critical flow, channel transitions, critical flow venturi-flume, standing wave flume and broad crested weir in discharge measurement. **(8L)**

Unit 2: Uniform flow: Flow resistance; composite roughness and compound channels, gradually varied flow, classifications and computations of free surface profiles, advanced numerical for flow profiles. **(7L)**

Unit 3: Varied flows: Gradually varied flow, basic principles and assumptions, spatially varied steady and unsteady surface flows, supercritical flows and oblique flows. **(7L)**

Unit 4: Rapidly varied flow: hydraulic jump in horizontal and sloped open channel bed and its characteristics, continuity and dynamic equations of unsteady flow, wave propagation and surge. **(7L)**

Unit 5: Unsteady flow: Wave celerity, classification of water waves according to relative depth, orbital motions, superposition, wave trains and wave energy, transformation of waves, dissipation of wave energy, positive and negative surges in rectangular channel, momentum and continuity equations, method of characteristics, dam-break problem. **(8L)**

References:

1. Townson, J. M. (2014). *Free-surface hydraulics*. CRC Press.
2. Montes, S. (1998). Hydraulics of open channel flow.
3. Akan, A. O. (2011). *Open channel hydraulics*. Elsevier.
4. Chanson, H. (2004). *Hydraulics of open channel flow*. Elsevier.
5. Srivastava, R. (2008). *Flow through open channels*. Oxford Higher Education.
6. Subramanya, K. (2019). *Flow in Open Channels, 5th edition*. Tata McGraw-Hill Education.

Course code: CE21XXX	**Hydraulics of Sediment Transport**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand the fundamental properties and formation processes of sediments.
CO2	Analyze the incipient motion of sediment particles.
CO3	Evaluate the various regimes of flow in natural streams.
CO4	Analyze flow resistance, velocity, sediment load distribution in alluvial channels.
CO5	Apply concepts of river meandering, braided river dynamics, and sediment sampling techniques for sediment transport analysis.

Course Contents:

Unit 1: Introduction: Sediment and fluvial hydraulics, nature of sediment problems, scope, origin and formation of sediments, fundamental properties of individual sedimentary particles, bulk properties of sediments. **(8L)**

Unit 2: Incipient motion of sediment particles: Properties, initiation of motion, bed load, bed forms, effective bed roughness, armouring, suspended load, total load, competent velocity, lift concept, critical tractive force, critical tractive stress of cohesive materials. **(7L)**

Unit 3: Regimes of flow: Description of regimes of flow, ripples and dunes regime, antidune regime, importance of regime of flow, prediction of regimes of flow, complexities of regimes in natural streams. **(7L)**

Unit 4: Resistance of flow and velocity distribution in alluvial channels: velocity distribution and resistance in turbulent flow over rigid boundaries, resistance to flow in alluvial streams, velocity distribution in alluvial streams. bed-load transport, early bed load equations, semi-theoretical equations. **(8L)**

Unit 5: Meandering of rivers, braided river, local scour at different structures, sediment sampling, mathematical models of sediment transport. **(7L)**

References:

1. Graf, W. H. (1984). *Hydraulics of sediment transport*. Water Resources Publication.
2. Mehta, A. J. (2013). *An introduction to hydraulics of fine sediment transport* (Vol. 38). World Scientific Publishing Company.
3. Garde, R. J., & Raju, K. R. (2000). *Mechanics of sediment transportation and alluvial stream problems*. Taylor & Francis.
4. Gyr, A. (2006). Sediment Transport. Springer. Book, ISBN 978-1-4020-5016-9.
5. Yang, C. T. (1996). Sediment Transport: Theory and Practice. Wiley.
6. Chien, N., & Wan, Z. (1999). Mechanics of Sediment Transport. American Society of Civil Engineers (ASCE).

Course code: CE21XXX	**Advanced Fluid Mechanics**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand the basic conservation laws and governing equations for Newtonian fluids.
CO2	Apply potential flow concepts.
CO3	Analyze viscous incompressible flows.
CO4	Understand the characteristics of boundary layers.
CO5	Analyze turbulent flow characteristics and theories.

Course Contents:

Unit 1: Basic Conservation and Governing Laws: Statistical & continuum methods, Eulerian and Lagrangian coordinates, material derivatives, control volumes, Reynolds' transport theorem (RTT), conservation of mass, momentum and energy, constitutive equations, Navier-Stokes equations-differential & integral approach, energy equations, governing equations for Newtonian fluids. **(8L)**

Unit 2: Potential Flows: Stokes stream functions, solution of potential equation, flow in a sector, flow around a sharp edge, flow near a blunt nose force and moment on a circular cylinder and sphere, conformal transformations, Elements of airfoil and wing theory. **(7L)**

Unit 3: Viscous Incompressible Flows: Exact solutions for Couette flow, Poiseuille flow, flow between rotating cylinders, Stokes' first problem, Stokes' second problem, pulsating flow between parallel surfaces, stagnation-point flow, flow in convergent and divergent

channels, flow over porous wall, Stokes approximation, rotating sphere in a fluid, uniform flow past a sphere and cylinder. **(8L)**

Unit 4: Introduction to Boundary Layer: Review of boundary layers: laminar and turbulent boundary layers, transition, separation. **(7L)**

Unit 5: Introduction to turbulence: Transition of flows, Origin of turbulence- its consequences, Physics of turbulent motion- concept of Reynolds stress, mean flow equations, Prandtl mixing length theory, Reynolds Equation. Characteristic scales of turbulence and order of magnitude- Kolmogorov scales, Isotopic and homogeneous turbulence. **(8L)**

References:

1. "Fundamental Mechanics of Fluids", I. G. Currie, CRC, Press, 2012.
2. "Foundations of Fluid Mechanics", S.W. Yuan, Prentice-Hall India Pvt. Ltd, New Delhi, 1967.
3. "Advanced Fluid Mechanics", K. Muralidhar & G. Biswas, Narosa Publishing, 2005.
4. "Boundary Layer Theory", H. Schlichting, 6th Edition, McGraw-Hill Inc., 1986.
5. "Turbulent Flow", R. J. Garde, 3rd Edition, New Age International Publishers, 2010.
6. "Modern Compressible Flow with Historical Perspective", John D. Anderson, McGraw Hill, 2017.
7. "Fundamentals of Fluid Mechanics", B.R. Munson, D.F. Young & T.H. Okiishi, John Wiley, 2020.
8. "Introduction to Fluid Mechanics", R.W. Fox & A.T. McDonald, 5th Edition, John Wiley, 2001.
9. "Viscous Fluid Flow", F. M. White and J. Majdalani, 4th Edition, McGraw-Hill, 2021.

Course code: CE21XXX	**Computational Fluid Dynamics**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand the basics of Computational Fluid Dynamics (CFD).
CO2	Analyze the finite difference method and its application to partial differential equations.
CO3	Evaluate the finite volume method application for PDEs.
CO4	Understand one-dimensional and multi-dimensional Finite element method.
CO5	Analyze and apply grid generation techniques in CFD.

Course Contents:

Unit 1: Introduction to CFD: Overview of CFD and its applications, governing equations of fluid dynamics, discretization methods for CFD, mathematical nature of PDEs and flow equations, types of grids used in CFD, CFD software packages. **(7L)**

Unit 2: Finite Difference Method in CFD: Introduction to finite difference method, discretization of partial differential equations, explicit and implicit schemes, solution of hyperbolic equations using finite difference method upwind and TVD schemes, solution of elliptic, hyperbolic and parabolic equations using finite difference method **(10L)**

Unit 3: Finite Volume Method in CFD: Introduction to finite volume method, control volume discretization and conservation laws, implicit and explicit time integration, solution of hyperbolic, elliptic, and parabolic equations using finite volume method **(8L)**

Unit 4: Finite Element Method: Basic functions, element and coordinate transformations, multi-dimensional elements, element integrals, optimal metric data, implementation sequence and global matrix. **(8L)**

Unit 5: Grid Generation and Post-Processing in CFD: Introduction to grid generation and post-processing in CFD, basics of structured and unstructured grids, mesh quality metrics, pre-processing of grids: visualization, cleaning, and refinement. **(8L)**

References:

1. Introduction to Computational Fluid Dynamics: Development, Application and Analysis by Atul Sharma, Springer Nature, 2022
2. Computational Fluid Mechanics and Heat Transfer (Computational and Physical Processes in Mechanics and Thermal Sciences) by John C. Tannehill, CRC Press, 2012.
3. An Introduction to Computational Fluid Dynamics: The Finite Volume Method" by H. K. Versteeg and W. Malalasekera, Pearson Prentince Hall, 2012.
4. Computational Fluid Dynamics by Hoffmann K.A. and Chiang, S.T., Engineering Education System, 2000.
5. Characteristics Finite Element Methods in CFD, Iannelli, J., Springer, 2006.
6. Applied CFD Techniques, Lohner, R., Wiley, 2008.
7. Finite Element Methods for CFD, Kuzmin, D. and Hamalainen, J., Siam Publishers, 2014.

Course code: CE21XXX	Water Resources Systems Planning and Management	Credits 3 - 1 - 0: 4

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to

CO1	Understand the basics of systems analysis and modelling.
CO2	Apply optimization techniques to solve water resources problems.
CO3	Understand and apply water resources planning models to real cases.
CO4	Analyze and apply water quality models.
CO5	Apply models for river basin management and urban drainage systems.

Course Contents:

Unit 1: Overview of the course, concepts of systems analysis, water resources planning, Modeling techniques, objectives and constraints, overview of optimization techniques. **(5L)**

Unit 2: Linear programming, dynamic programming, stochastic optimization, multi-objective optimization, simulation techniques, decision making under uncertainty, fuzzy optimization. **(8L)**

Unit 3: Water resources planning, data collection, future water demands, models for water resources planning, sensitivity analysis, case studies.

Unit 4: Water quality modelling: River water quality monitoring, models, catchment scale water quality models, water quality in lakes and reservoirs, ground water quality. **(8L)**

Unit 5: Water resources management: River basin modelling, reservoir storage-yield relation, reservoir design and operation, models for integrated water resources management, decision support systems, inter-basin water transfer, urban water systems, modelling, urban drainage systems. **(8L)**

References:

1. Water Resources Systems Planning and Management – An introduction to methods, models and applications, Loucks, D.P. and Eelco van Beek, Springer, 2017.
2. Water Resources Systems Modeling Techniques and Analysis, Vedula, S. and Mujumdar, P.P., Tata McGraw Hill Pub. Co., 2005
3. Water Resources Systems Planning and Management, Jain, S.K. and Singh, V.P., Elsevier Science, 2003.
3. Water Resources Systems Planning and Analysis, Loucks, D.P., Stedinger, J.R. and Haith, D.A., Prentice Hall Inc., 1982
4. Civil and Environmental Systems Engineering, Charles, S.R., Whitlatch, E.E., and Wright, J.R., Pearson Education Inc., 2004
5. Water Resources Planning, Dzurik, et al., Rowman and Littlefield Publishers, 2018.

ELECTIVE-II

Course code: CE21XXX	Groundwater Hydrology	Credits 3 - 1 - 0: 4

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand groundwater in hydrologic and aquifer systems.
CO2	Understand well hydraulics.
CO3	Analyze groundwater movement and equations governing the flow
CO4	Create groundwater management strategies.
CO5	Analyze climate change impacts on groundwater resources and water availability.

Course Contents:

Unit 1: Introduction to Groundwater: Ground water availability, groundwater in the hydrologic system, hydrologic budget, vertical distribution of subsurface strata, types of aquifers, aquifer characteristics. **(8L)**

Unit 2: Well hydraulics: Types of wells, two wells, a line of wells, tube well, well irrigation, open wells, yield of open well, methods of increasing yield, site selection of well, well logging, well construction techniques, well completion. **(8L)**

Unit 3: Groundwater flow hydraulics: Darcy's law, hydraulic conductivity and intrinsic permeability, transmissivity, stream function, flow net, partial differential equations governing groundwater flow in aquifers, steady flow in confined and unconfined aquifers, radial flow problems. **(7L)**

Unit 4: Groundwater Management: Concept of basin management, conjunctive use of surface water and groundwater, groundwater management techniques. **(7L)**

Unit 5: Climate Change Impacts on Groundwater: Hydrological components affecting the groundwater, direct impacts of climate change on groundwater, indirect impacts of climate change on groundwater, climate change impacts on water availability in aquifer pumping equipment for sanitary protection of wells, collector wells. **(8L)**

References:

1. Todd, D. K., Ground water Hydrology, John Wiley & Sons, New York, 1995
2. Freeze, Allen R. and Cherry, John A. "Ground Water ". Prentice Hall Inc., 1979.
3. Garg, S. K. "Water Resources Engineering ", Khanna publishers, Delhi, 1973.
4. Punmia, B. C. "Water Resources Engineering ", Lakshmi Publications, New Delhi, 1969.

5. Engineering Hydrology, Subramanya, K and Sharma,P.K, Tata McGraw Hill Publications, 2014 6th Edition
6. Groundwater Hydrology, Chahar, B. R., McGraw Hill Education (India) Private Limited, New Delhi, 2015.
7. Groundwater hydrology by Agarwal, V.C., PHI Learning, 2012.

Course code: CE21XXX	**Stochastic Hydrology**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand hydrology concepts and apply probability theories in hydrology.
CO2	Analyze frequency distributions of hydrologic extremes.
CO3	Apply correlation and regression techniques in hydrologic modeling.
CO4	Analyze hydrologic time series analysis methods.
CO5	Evaluate hydrologic time series models.

Course Contents:

Unit 1: Introduction: Deterministic and stochastic hydrology, review of concepts of probability, random variables and their properties, probability distribution and probability density function, discrete and continuous probability distributions used in hydrology, maximum likelihood method and method of probability weighted moments. **(8L)**

Unit 2: Frequency analysis of hydro climatic extreme: Extreme value distributions, analysis of floods, droughts and other natural hazards, regional flood frequency analysis, risk and reliability in hydrologic design, analysis and measures of hydrologic uncertainty. **(7L)**

Unit 3: Correlation analysis and correlation coefficient: Simple linear regression, multivariate regression analysis, correlation coefficient and its significance in regional analysis, analysis of variance, applications – rainfall-runoff analysis, rating curves, multivariate analysis, principal component analysis, cluster analysis. **(7L)**

Unit 4: Hydrologic Time Series Analysis: Hydrologic time series, stationary and non-stationary time series, ensemble and realization, trend analysis, trend removal, analysis of periodicity, Fourier transformation and harmonic analysis, autocorrelation function, spectral density function, wavelet analysis. **(7L)**

Unit 5: Modeling of Hydrologic Time Series: Time series models, autoregressive and moving average models, periodic models, simulation of hydrologic time series, First

order Markov process, Markov chain, multi-site time series model, cross-correlation, theory of copula and its use in hydrology, commonly used copula functions, selection of best fit copula, uses of copula hydrologic. **(8L)**

References:

1. Stochastic Water Resources Technology, Kotteguda, N.T., The Macmillan Press, New York, 1982
2. Statistical Methods in Hydrology and Hydroclimatology, Rajib Maity, Springer Nature Singapore Pte Ltd., 2018
3. Irrigation & Drainage Eng., by Peter Waller and Muluneh Yitayew, Springer, 2016
4. Statistical Methods in Hydrology, Haan T. C., East West Publishers, 2002
5. Statistics, Probability and Reliability for Civil and Environmental Engineers, Kotteguda, N.T., and Resso, R., Blackwell Publishing, UK, 2008.

Course code: CE21XXX	**Watershed Modeling**	**Credits 3 -1-0: 4**

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand various hydrologic model types.
CO2	Analyze hydroclimatic and geospatial inputs for hydrologic model.
CO3	Apply rainfall-runoff modeling techniques for ungauged basins.
CO4	Evaluate watershed modeling for hydrologic forecasting.
CO5	Design watershed management strategies.

Course Contents:

Unit 1: Introduction to Hydrologic Models: Empirical, physics-based, and data-driven models lumped and distributed models, stochastic and deterministic models, event and continuous models**.** **(7L)**

Unit 2: Hydrologic Model Inputs: Hydro climatic inputs and their analysis, geospatial inputs and their processing, model development, lumped, semi-distributed, and distributed models**.** **(7L)**

Unit 3: Rainfall-runoff Modeling: Empirical methods, SCS-CN method, runoff estimation for ungauged basins, scale and scaling in rainfall–runoff modeling **(7L)**

Unit 4: Watershed Modeling: Physics-based, and data-driven hydrological modelling, calibration and validation, model performance evaluation, hydrologic forecasting, indicators of hydrologic alterations. **(7L)**

Unit 5: Watershed Management: Principles and strategies of watershed management through distributed hydrological modeling, soil water conservation practices, integrated planning, multidisciplinary approach, management of agricultural land, structural and nonstructural measures, erosion and soil salinity problems and controlling techniques, gully control, landslide and correction techniques. **(8L)**

References:

1. Singh, V. P. (2017). Handbook of applied hydrology. McGraw-Hill Education.
2. Maidment, D. R. (1996). Handbook of hydrology. McGraw-Hill Professional.
3. Beven, K. J. (2011). Rainfall-runoff modelling: The primer. John Wiley & Sons.
4. Remesan, R., and Mathew, J. (2016). Hydrological data driven modelling. Springer International.
5. J V S Murthy, (2004). Watershed Management, New Age International (P) Limited Publishers, New Delhi, Reprint.

Course code: CE21XXX	**Urban Water Management**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand urbanization's effects on the hydrological cycle.
CO2	Analyze and design an urban drainage master plan integrating water resources with urban planning.
CO3	Evaluate approaches to urban drainage systems
CO4	Design and analyze performance of stormwater network systems.
CO5	Evaluate models for stormwater management.

Course Contents:

Unit 1: Introduction: General introduction to urbanization and its effect on water cycle, urban hydrological cycle, trends in urbanization, effect of urbanisation on hydrology, concepts of Smart City. **(8L)**

Unit 2: Urban Drainage Plan: Master drainage plans, issues to be concentrated upon, typical content of an urban drainage master plan, interrelation between water resources investigation and urban planning processes, planning objectives, comprehensive planning, use of models in planning **(7L)**

Unit 3: Basic approaches to urban drainage, Time of concentration, importance of short duration of rainfall and runoff data, methods of estimation of time of concentration for

design of urban drainage systems, runoff quantity and quality, wastewater and storm water reuse, major and minor systems, Elements of drainage systems, open channel, underground drains, appurtenances, pumping, source control. **(7L)**

Unit 4: Storm water Analysis: Calculation of runoff and peak, design of stormwater network systems, performance evaluation of urban drainage systems, best management practices, detention and retention facilities, constructed wetlands. **(7L)**

Unit 5: Operation and maintenance of urban drainage system, interaction between stormwater management and solid waste management, various model available for stormwater management, legal aspects **(8L)**

References:

1. Manual on Storm Water Drainage Systems, Central Public Health and Environmental Engineering Organization, MOHUA, 2019
2. Manual on Drainage in Urban Areas, 2 Volumes, Geiger, W.F., Marsalek, J. Z., and Rawls, G.J., UNESCO, 1987
3. Urban Hydrology, Hall, M.J., Elsevier, 1984
4. Storm Water Detention for Drainage, water quality and CSO Management, Stahre, P. and Urbonas, B., Prentice Hall, 1990
5. Storm Water Management, Wanielista, M.P. and Yousef, Y.A., John Wiley and Sons Inc., 1993

Course code: CE21XXX	**Glaciology**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand glacial environments and glacier characteristics, dynamics.
CO2	Analyze snow and glaciers hydrology.
CO3	Evaluate glacier dynamics.
CO4	Apply knowledge of glaciers' responses to climate change and permafrost significance.
CO5	Develop strategies for assessing glacial hazards and monitoring glacial changes.

Course Contents:

Unit 1: Introduction: Introduction to glacial environments, glaciers, snow, ice sheets and sea ice, glacier characteristics, glacier meteorology, glacier dynamics and mass balance., glacier mass balance, supraglacial, englacial, and basal hydrology. **(8L)**

Unit 2: Surface energy balance of snow and glaciers: snow and glacier hydrology, ice age theories, ice cores and paleaoclimate. **(7L)**

Unit 3: Glacier Dynamics: Types of glacier dynamics, Glacier Dynamics I - Internal deformation, Glacier Dynamics II - Basal sliding, Glacier Dynamics III - the role of deformable sediments, glacier surging. **(7L)**

Unit 4: Glacier and its impact on Climate change: Glaciers' response to changing climate, melting glaciers and sea level rise, permafrost and its features, glaciological aspects and the climate record, applications of remote sensing techniques for glacial change monitoring with respect to climate change. **(7L)**

Unit 5: Glacial hazards, Types of glacial hazards, glacial lake outburst floods in the himalayas, glacial hazard assessment and mitigation, current issues and possible adaptations. **(8L)**

References:

1. Physics of Glaciers by K. Cuffey and W.S.B. Paterson, Elsevier, 2010.
2. The Cryosphere by S.J. Marshall, Princeton University Press, 2012.
3. Glacial Geologic Processes by D.J. Drewry, Hodder Arnold, 1996.
4. The Microclimate of Valley Glaciers by J. Oerlemans, Utrecht Publishing, 2010.
5. Irrigation & Drainage Eng., by Peter Waller and Muluneh Yitayew, Springer, 2016.
6. Thomas M Cronin: Paleoclimates: Understanding Climate Change Past and Present, Columbia University Press, 2010.
7. Raymod S Bradley: Paleoclimatology, Volume 68, Second Edition: Reconstructing Climates of the Quaternary (International Geophysics), Academic Press, 1999.
8. K M Cuffey and W S B Paterson: The physics of Glaciers, Academic Press, 2010.
9. C J Van der veen: Fundamentals of Glacier Dynamics, CRC Press, 2013.

ELECTIVE-III

Course code: CE21XXX	Fluid-structure Interaction	Credits 0 - 0 - 4: 4

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand flow characteristics around bluff bodies and circular cylinders.
CO2	Analyze flow behavior around non-circular cylinders.
CO3	Evaluate flow interference between multiple cylinders in various arrangements.
CO4	Analyze flow-induced vibrations (FIV) in oscillating cylinders.
CO5	Apply FIV in engineering problems.

Course Contents:

Unit 1: Introduction to bluff body flows: factors influencing bluff body flows, boundary layer, flow separation, wake formation-vortex shedding, flow over stationary isolated circular cylinder: classification of flow regimes based on Reynolds number (Re), laminar states of flow, steady laminar wake- periodic laminar. **(7L)**

Unit 2: Flow over non-circular cylinders: Influence of geometry and Re- flow separation-wake structures, vortex shedding and induced forces. **(7L)**

Unit 3: Flow interference: Flow interference between two circular cylinders-tandem, side-by-side and staggered arrangements, classification of interference regimes, effect of spacing-flow patterns and surface pressure distribution - biased gap flow - induced forces (lift & drag), Flow over cylinder clusters (multiple cylinders). **(7L)**

Unit 4: Flow-induced vibrations (FIV): Influencing factors, body geometry-reduced velocity - free stream turbulence, flow incidence, mass ratio, damping, added mass, vortex-induced vibration galloping-flutter-fluid elastic excitation-turbulence buffeting-other types, Flow structures around oscillating cylinders-induced forces and cylinder response-equations of motion-modal analysis, Interference effects in FIV, FIV in engineering codes, experimental measurements, flow visualization. **(8L)**

Unit 5: Practical problems: Tube bundle vibrations in heat exchangers and nuclear reactors-Vibrations of stacks and other tall structures, transmission line vibrations, passive and active control of FIV, energy extraction from FIV. FSI in biological systems: blood flow through arteries and veins-diagnosis of diseases. **(8L)**

References:

1. Robert D. Blevins, Flow-Induced Vibration, 2nd Edition, Van Nostrand Reinhold, New York, USA, 1990.
2. E. Naudascher, and D. Rockwell, Flow-Induced Vibrations: An Engineering Guide, Dover publishers, USA, 2005.
3. M. M. Zdravkovich, Flow around circular cylinders, Vol.1: Fundamentals, Oxford University Press, Oxford, England.1997.
4. M. M. Zdravkovich, Flow around circular cylinders, Vol.2: Applications, Oxford University Press, Oxford, England.1997.
5. Thomson, W. T and Dahleh, M. D., Theory of vibrations with Applications, Prentice Hall, 1997.
6. Rao, S.S., Mechanical Vibrations, Pearson Education, 2004

Course code: CE21360	**Numerical Computation and Simulation**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand the key differences between MATLAB, C++, and FORTRAN 90 for solving engineering problems.
CO2	Create MATLAB for loops, arrays, matrices, plotting, and debugging.
CO3	Design solutions for linear and nonlinear systems, and apply curve fitting techniques using MATLAB.
CO4	Apply MATLAB for engineering problem-solving.
CO5	Create solutions for engineering problems involving ODEs using MATLAB tools.

Course Contents:

Unit 1: Introduction to MATLAB, C++, FORTRAN 90 and basic difference of each programme. **(6L)**

Unit 2: MATLAB: Advantages and disadvantages of MATLAB, Input and Output statement, loops, Iteration and floating types, construction of arrays and matrices, MATLAB functions, plotting, debugging programs. **(8L)**

Unit 3: Solutions to the systems of linear equations and nonlinear equations, Numerical and curve fitting, Finite difference techniques. **(8L)**

Unit 4: Numerical Integration and differentiation- applied engineering problems and solving using MATLAB programming. **(8L)**

Unit 5: Ordinary differential equations- applied engineering problem and solving using MATLAB programming. Engineering problems solving with MATLAB tools. **(10L)**

References:

1. V. Rajaraman , "Computer Oriented Numerical Methods" Prentice Hall of India, , 2006
2. Steven C. Chapra and Raymond P. Canale, "Numerical Methods for Engineers" Tata McGraw Hill, New Delhi, 2010.
3. M. K. Jain, S. R. K. Iyenger and R. K. Jain, "Computational Methods for Partial Differential Equations", New Age International (P) Limited, 2003.
4. Andrew Knight, "Basics of MATLAB and beyond" Chapman & Hall/CRC, 2011.
5. Stephen J. Chapman, "MATLAB Programming for Engineers", Thomson Asia Pte. Ltd., Australia, 2008.
6. Delores M. Etter, "Engineering Problem solving with MATLAB", Prentice Hall, New Jersy, 1997.
7. Dean G. Duffy, "Advanced Engineering Mathematics with MATLAB" Chapman & Hall/ CRC Press, 2011.
8. S. R. Otto and J. P. Denier, "An Introduction to Programming and Numerical Methods in MATLAB", (Springer: New Age International), John Wiley and Sons, Inc., New York, 2002.
9. Won Y. Yang, Wenwe Cao, Tae Sang Chung, and John Morris, "Applied Numerical Methods using MATLAB" John Wiley & Sons, Inc., Publication, 2005.

Course code: CE21XXX	**Computational Methods in Water Resources Engineering**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand computational and statistical methods in Civil Engineering.
CO2	Analyze numerical techniques for solving non-linear equations and integration.
CO3	Evaluate ordinary differential equations and their applications in water resources systems.
CO4	Apply finite difference methods to solve partial differential equations.
CO5	Apply skills in the Finite Element Method for water resources systems applications.

Course Contents:

Unit 1: Overview of the course, the need for computational and statistical methods, overview of the applications in Civil Engineering in general and Water Resources and Environmental Engineering in particular. **(8L)**

Unit 2: Review of numerical techniques for finding roots of non-linear equations and numerical integration. **(7L)**

Unit 3: Ordinary differential equations, nature of problems, boundary and initial conditions, Euler's method, modified Euler's method, predictor-corrector methods, Runge-Kutta methods, boundary value problems, applications for reservoir routing, gradually varied flow problems, pipe networks. **(7L)**

Unit 4: Partial differential equations, classification, nature of problems, concepts of finite difference method, finite difference schemes, solution of parabolic equations, pollutant transport, solution of elliptical equations, solution of Laplace equation and Poisson equation. **(7L)**

Unit 5: Basic concepts of Finite Element Method, FEM versus FDM, element shapes, shape functions, development of shape functions for linear elements, formulation of FEM for stress analysis problems, flow through porous media, Galerkin's method and variational method for formulation of stiffness matrix, flow through porous media, unsteady flow through open channels, propagation of waves, concepts of finite volume method. **(8L)**

References:

1. Numerical Methods for Engineers and Scientists, Hoffman, J.D., CRC Press, Special Indian Edition, 2011
2.Statistics, Probability and Reliability for Civil and Environmental Engineers, Kotteguda, N.T. and Renzo Resso, McGraw Hill Companies Inc., New York, 1998.
3.Applied Numerical Methods for Engineering, Schilling, R.J., and S.L. Harris, CENGAGE Learning, India Edition, 2007
4. Computational Hydraulics,Abbot, M.A. and Vervey, Elsevier Publications, 1996
5.The Finite Volume Method in Computational Fluid Dynamics, Moukalled, F., Mangani, L., Darwish, M., Springer International Publishing, 2015

Course code: CE21357	**Soft Computing Methods in Engineering Problem Solving**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand the fundamental concepts and principles of soft computing techniques
CO2	Analyze and compare different soft computing approaches for problem-solving
CO3	Apply soft computing methods to solve complex engineering problems
CO4	Design and implement algorithms using artificial neural networks, fuzzy systems, and genetic algorithms
CO5	Design hybrid soft computing systems for enhanced problem-solving capabilities

Course Contents:

Unit 1: Introduction and Working Principles: Background, definitions, classification of soft computing techniques, advantages, limitations, working principles of soft computing techniques - Fuzzy logic, Artificial Neural Networks (ANN), Genetic Algorithms (GA),and other evolutionary techniques, examples in real life, historical context, key concepts. (**6L**)

Unit 2: Artificial Neural Networks: Principle, architectures, single-layer networks, multi-layer networks, recurrent networks, learning approaches in neural networks - supervised, unsupervised, and reinforcement learning, key ANN algorithms - backpropagation, Self-Organizing Maps (SOM), applications of neural networks in engineering. (**8L**)

Unit 3: Fuzzy Systems: Fuzzy sets, fuzzy numbers, fuzzy relations, fuzzy measures, fuzzy logic and the theory of uncertainty and information, fuzzy inference systems - Mamdani-type and Sugeno-type, defuzzification methods, Engineering applications of fuzzy systems. (**8L**)

Unit 4: Evolutionary Algorithms: Genetic algorithm and traditional optimization methods, simple genetic algorithms - representation and encoding, selection methods, crossover operators, mutation operators, analysis of GA operators, deception, working principles of genetic algorithms, multimodal and multi-objective optimization methods, constraint handling, Introduction to other evolutionary computation techniques – Ant Colony Optimization, Particle Swarm Optimization, Differential Evolution, Engineering applications. (**8L**)

Unit 5: Hybrid Systems and Applications of Soft Computing: Necessity, combined use of Fuzzy and ANN, neuro-fuzzy systems - Adaptive Neuro-Fuzzy Inference System (ANFIS) and fuzzy neural networks, combined use of ANN-GA, evolutionary neural networks, fuzzy-genetic systems, Case studies and general applications in engineering - control systems, pattern recognition, optimization problems, data mining and knowledge discovery, emerging trends in soft computing. (**12L**)

Term Paper

Students will complete a term paper involving the application of soft computing techniques to solve a real-world engineering problem. The term paper will include problem definition, literature review, algorithm selection and implementation, experimental analysis, results, written report, and oral presentation.

References:

1. Deb, K., “Evolutionary Multiobjective Optimization Algorithms” John Wiley & Sons Ltd., 2001.
2. Goldberg, D. E., “Genetic Algorithms in Search, Optimization and Machine learning”, Addison-Wesley Publishing Co., 1989.
3. Haykin, S. “Neural networks and learning machines”, Pearson Education India, 2009.

4. Ross, T.J., “Fuzzy Logic with Engineering Applications”, Wiley, 1995.
5. Negnevitsky, M.. Artificial Intelligence: A Guide to Intelligent Systems. Pearson Education, 2011.
6. Jang, J.S.R., Sun, C.T., and Mizutani, E. Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence. Upper Saddle River, NJ: Prentice Hall, 1997.
7. Engelbrecht, A.P. "Computational Intelligence: An Introduction", Wiley, 2007.

Course code: CE21359	**Artificial Intelligence for Remotely Sensed Image Processing and GIS**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to:

CO1	Understand optical remote sensing.
CO2	Understand and apply remote sensing satellite image processing techniques.
CO3	Design strategies for geospatial information storage, management and modelling.
CO4	Evaluate AI, ML, ANN and Deep Learning techniques in remote sensing.
CO5	Apply OSS for use in image processing and GIS.

Course Contents:

Unit- 1: Remote Sensing: Introduction to the course, physics of remote sensing, remote sensing system, spectral reflectance curves, resolution and multi-concept, sensors and platforms, FCC, remote sensing satellites and data products. **(8L)**

Unit- 2: Satellite Image Processing: Satellite Image- characteristics and formats, image statistics, land use and land cover classification system, image rectification, image enhancements, pattern recognition, image classification- unsupervised and supervised. **(7L)**

Unit- 3: Geographic Information System (GIS): Geographic data and topology, GIS and its components, datums and map projection, data acquisition, data models, geospatial database creation, data organization, query formation, buffering, spatial overlay, data output, network analysis, introduction to Web GIS. **(7L)**

Unit- 4: Artificial Intelligence (AI): History and fundamentals, current trends in AI, basics of Internet of Things (IoT), Intelligent systems, Machine Learning (ML), Artificial Neural Network (ANN), Multilayer Perceptron, Learning Algorithms, introduction to Deep Learning. **(7L)**

Unit- 5: Open Source Software (OSS) and Applications: OSS fundamentals, open data and open standards, training on OSS in the field of GIS and image processing, applications of knowledge of remote sensing, image processing, GIS and AI in the field

of environmental, transportation and water resource engineering, and climate change and for societal applications. **(8L)**

References

1. Remote Sensing & Image Interpretation: T.M. Lillesand & R.W. Kiefer, Wiley Students Edition, India, 2011.
2. Principles of Geographical Information Systems: Peter A. Burrough & Rachael A. McDonnell, Oxford University Press, 2015.
3. Computer Processing of Remotely Sensed Images: P.M. Mather, John Wiley & Sons., 2004.
4. Principles and Theory of Geoinformatics: P.K. Garg, Khanna Book Publishing, Delhi, 2020.
5. Remote Sensing and GIS: M. Anji Reddy, BS Publications, Hyderabad, 2012.
6. Artificial Intelligence: Kevin Knight, Elaine Rich, Shivashankar B. Nair, 3rd ed. TMH, 2008.
7. Artificial Intelligence: Structures and Strategies for Complex Problem Solving, George F Luger, 6th edition, Pearson, 2008.
8. Neural Networks and Learning Machines: Simon Haykin, 3rd ed., Pearson, 2008.

ELECTIVE COURSES
SEMESTER II (EVEN)

ELECTIVE-IV

Course code: CE22XXX	Climate and Climate Change Modelling	Credits 3 - 1 - 0: 4

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to

CO1	Understand the concept of climate system and climate feedback mechanisms.
CO2	Analyze climate change drivers, variability, and scenarios across different temporal scales.
CO3	Evaluate climate modeling techniques, including simple models, General Circulation Models, and downscaling methods.
CO4	Analyze the impact of climate change on hydrological processes and future water resources.
CO5	Design climate change adaptation methodologies and their application in India.

Course Contents:

Unit 1: Description of the climate system: Basic concept of climate, climate & weather, climatic classification, GHG emission, IPCC, teleconnections, climate and land-use feedback **(8L)**

Unit 2: Climate Change & Variability: Climate change drivers, past, present and future climate change, climate variability on various spatio-temporal scales, climate change scenarios over India **(7L)**

Unit 3: Climate Modelling: Simple climate models, General Circulation Models, coupled models, Statistical and dynamic downscaling (**10L)**

Unit 4: Impact of climate change on hydrological processes, and hydrological extremes, assessment of future water resources **(8L)**

Unit 5: Climate Change Adaptation: Climate change adaptation capacity and methodology analysis, adaptation aspects over India **(6L)**

References:

1. Climate change modeling, mitigation, and adaptation, Rao Y.S., Zhang, C.T., Ojha, C.S.P., Gurjar, B.R., Tyagi, R.D. & Kao C.M., ASCE, 2013
2. Climate System Modeling, Kevin E Trenberth, Cambridge University Press, 2010
3. The Climate Modeling Premier, Kendal McGuffie, Ann Henderson-Sellers, WileyBlackwell, 2014, 4th Edition

4. Climate Change: What Everyone Needs to Know, Joseph J. Romm, Oxford University Press, 2016
5. IPCC Sixth Assessment Report, 2021.

Course code: CE22XXX	**Climate Change and its impact on Water Resources**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE
Course Outcomes: At the end of the course, the student will be able to

CO1	Understand climate variability, climate change, and trends in hydro-meteorological data.
CO2	Evaluate climate models for simulation of climate systems.
CO3	Analyze climate change consequences under different emission scenarios.
CO4	Apply downscaling techniques for climate data.
CO5	Analyze the impacts of climate change on water resources.

Course Contents:

Unit 1: Introduction: Climate Variability, Sustainable Development Goals (SDGs), causes of climate change: greenhouse effect, evidence of climate change, trend analysis of hydro-meteorological data, paleoclimate –learning from the past. **(6L)**

Unit 2: Simulation of Behavior of the Climate System: Physics and Earth's climate, global carbon cycle, global climate models and climate feedbacks, coupled model systems, climate archives and climate data. **(9L)**

Unit 3: Methodology to study climate change impacts on water resources: GHG emission scenarios and their purpose, Representative Concentration Pathways (RCP). **(7L)**

Unit 4: Downscaling Climate Data: Dynamical downscaling, statistical downscaling, transfer function-based methods, weather generators, weather typing. **(8L)**

Unit 5: Impacts of Climate Change on Water Resources: Hydrologic modeling to determine impacts, impacts on hydrologic extremes, impact of climate change on environment, societal impacts of climate change, uncertainties in climate predictions. **(8L)**

References:

1. Dessler, A.E., Introduction to Modern Climate Change, Cambridge University Press 2012
2. Farmer, G. Thomas and John Cook. Climate Change Science: A Modern Synthesis. Springer 2013

3. IPCC, SRES, N. Nakićenović, R. Swart (Eds.). Special Report on Emissions Scenarios: A Special Report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press. 2000
4. Jain, Sharad K., and V P Singh, Engineering Hydrology: An Introduction to Processes, Analysis, and Modeling, McGraw Hill Education. 2019
5. Jain, S.K., and P.K. Singh (2019) (Editors). Climate change and its impacts on water resources with focus on India. Special Report – 1/19, National Institute of Hydrology, Roorkee. 275pp. 2019
6. Nagesh Kumar, D. and K. SrinivasaRaju. Impact of Climate Change on Water Resources: With Modeling Techniques and Case Studies. Springer 2017
7. vanVuuren, D. P., J. Edmonds, M. Kainuma, K. Riahi, A. Thomson, K. Hibbard, G. C. Hurtt, et al. The representative concentration pathways: An overview. Climatic Change. 109:5, 2011. doi:10.1007/s10584-011-0148-z. 2011

Course code: CE22XXX	**Climate Variability and Global Warming**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to

CO1	Understand climatology, atmospheric and oceanic variables.
CO2	Analyze the global energy balance and greenhouse effects.
CO3	Evaluate atmospheric and oceanic fluid dynamics influence on regional climate
CO4	Evaluate climate variabilities from atmosphere-ocean interactions.
CO5	Analyze climate forcing and feedback mechanisms behind climate change.

Course Contents:

Unit 1: Introduction to Climatology and Climatic Variables, Atmospheric Variables, Variations in weather and climate, impact of global warming on stability and lapse rates, oceanic variables, cryosphere. **(7L)**

Unit 2: The global energy balance, energy flux and variabilities in solar radiation, Greenhouse effect, radiative energy fluxes, Lambert-Beer law, radiative equilibrium model, Greenhouse effect in stratified atmosphere, radiation and the clouds. **(6L)**

Unit 3: Atmospheric fluid dynamics, large scale circulation patterns and climate types, oceanic fluid dynamics, mixed layers, wind driven circulation, regional climate. **(8L)**

Unit 4: Climatic variabilities due to atmosphere-ocean interactions, ntra-seasonal and inter-annual variabilities, PNA, NAO, SAM, MJO and ENSO variabilities, decadal variations of weather and climate. **(8L)**

Unit 5: Physics of Climate Change: Climate forcing, climate sensitivity and feedback - measures of forcing, sensitivity and feedback, radiative feedback, dynamical feedback in

energy transport, cloud feedback, bio-geochemical feedback. overview of current anthropogenic forcing. **(8L)**

References:

1. An Introduction to Atmospheric Physics, David G. Andrews, Cambridge University Press, 2010. ISBN: 9780511800788
2. Global Physical Climatology, Elsevier 2nd Edition - December 3, 2015. Author: Dennis L. Hartmann Hardback ISBN: 9780123285317
3. Meteorological Measurements and Instrumentation Author(s):R. Giles Harrison, 2015 John Wiley & Sons, Ltd, Print ISBN:9781118745809
4. Physical Principles of Remote Sensing, W. G. Rees,3rd Edition, Cambridge University Press, ISBN 9781139017411
5. IPCC Sixth Assessment Report, 2021.

Course code: CE22XXX	**Climate change vulnerability and mitigation**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE
Course Outcomes: At the end of the course, the student will be able to

CO1	Understand climate change, greenhouse effect, and the global carbon cycle.
CO2	Analyze role of plants and agriculture in organic carbon sequestration.
CO3	Evaluate the role of forests in the global carbon cycle, and biomass accumulation in climate change mitigation.
CO4	Assess the impact of climate change on cities and developing countries.
CO5	Design flood prevention and climate change adaptation strategies to live with the flood.

Course Contents:

Unit 1: Weather and climate, natural vs anthropogenic climate change, Greenhouse effect, global carbon cycling, carbon budget, atmospheric carbon inventory, carbon inventory of the biosphere, soils, oceans and Lithosphere. **(8L)**

Unit 2: Organic carbon sequestration in plant biomass and soils, greenhouse gas emission trends from agriculture, management of greenhouse gases sources and sinks, technologies for carbon sequestration enhancement. **(7L)**

Unit 3: Role of forests in global carbon cycle, estimation global forest area trends, global forest biomass accumulation, climate change mitigation options under forest, blue carbon ecosystems and climate change. **(7L)**

Unit 4: Impact of climate change on cities and developing countries, sea-level rise adaptation, environmental management systems, economic climate change mitigation approaches. **(7L)**

Unit 5: Flood mitigation in urban areas: Climate change as primary cause of urban flooding, flood prevention – structural and non-structural measures, land use planning, floodplain management, flood risk mapping, flood early warning system, climate change adaptation strategies – flood proofing, elevated floor, floating platforms, flood gates, flood barriers. **(7L)**

References:

1. Ussirim D.A.N., and Lal, R. Carbon Sequestration for Climate Change Mitigation and Adaptation, Springer International Publishing, 2017.
2. Štreimikienė, D. and Mikalauskiene, A. Climate Change and Sustainable Development: Mitigation and Adaptation, CRC Press, 2021.
3. Kevin E Trenberth: Climate System Modeling, Cambridge University Press, 1992.
4. Kendal McGuffie, Ann Henderson-Sellers: A Climate Modeling Premier, Wiley, 2014.
5. Stagner, J.A., and Ting, D.S.K., Climate Change and Pragmatic Engineering Mitigation, Jenny Stanford Publishing, 2022.
6. Climate Change synthesis report (2023), IPCC.
7. IPCC Sixth Assessment Report, 2021.

Course code: CE22XXX	**Coastal Processes and Climate Change**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to

CO1	Understand water wave fundamentals and wave theories.
CO2	Analyze surf zone hydrodynamics, and wave statistics.
CO3	Apply long waves theory to natural hazards.
CO4	Analyze coastal morphodynamics.
CO5	Evaluate climate change impacts, and design coastal protection structures.

Course Contents:

Unit 1: Introduction to water waves, wave theories, small amplitude shallow water waves, sine waves in arbitrary depth, Waves of finite height, diffraction, reflection, standing waves. **(10L)**

Unit 2: Surf zone hydrodynamics, surf zone waves, wave setup, swash and runup, longshore currents, rip currents, natural waves, wave statistics. **(9L)**

Unit 3: Long waves, wind driven circulation, storm surge, tides, predicted and measured tides, tsunami, density driven flows in estuary, coastal ground water dynamics. **(7L)**

Unit 4: Morphodynamics, beach profiles, beach plan-forms, sediment budget, Brunn's rule, 2D and 3D sediment budgets, beach nourishment techniques. **(5L)**

Unit 5: Climate change, global warming, ocean circulation, sea level rise, cyclone impacts on coastlines, coastal protection structures such as seawalls, breakwaters, nature based solutions. **(6L)**

References:

1. Nielsen, P. 2009. Coastal and Estuarine Processes, Advanced Series on Ocean Engineering.
2. Dean and Darlymple, 1984. Wave mechanics for water engineers and scientists. Advanced Series on Ocean Engineering
3. Sundar, V. 2018 Coastal Engineering, Advanced Series on Ocean Engineering.
4. Sundar, V. 2023. Coasts and Estuaries: Management and Engineering, Advanced Series on Ocean Engineering
5. Reeve, D., Chadwick, A., and Fleming, C. 2018. Coastal Engineering: Processes, Theory and Design Practice. Taylor&Francis Group.
6. Sorensen, R. 2013. Basic Coastal Engineering, Springer US.

ELECTIVE-V

Course code: CE22XXX	Design of Hydraulic Structures	Credits 3 - 1 - 0: 4

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to

CO1	Understand principles of designing irrigation hydraulic structures.
CO2	Evaluate stability and safety of gravity, earth and rock fill dams.
CO3	Analyze various dam outlet structures.
CO4	Design canal regulation structures, and cross drainage works.
CO5	Apply hydraulic modeling principles design of physical models.

Course Contents:

Unit 1: Principles of designing irrigation hydraulic structures and Headworks- Bligh's theory, Khosla's theory for determination of pressure and exit gradient, hydraulic jump. canal head works, layout of head work, weir, canal head regulator, silt control at head work. **(10L)**

Unit 2: Types of dams and their characteristics- Gravity dams, forces acting, method of analysis, modes of failure and factors of safety, stability analysis, galleries. earth dam, foundation, materials, criteria for safe design, typical sections, compaction of rock fill dam. **(10L)**

Unit 3: Dam outlet works: types of outlet structures, ogee spillway, chute spillway, siphon spillway, side channel spillway, labyrinth and piano key weir, spillway gates. **(6L)**

Unit 4: Canal regulation structures: Design of cross drainage works, canal drops, head and cross regulators, canal outlets. **(7L)**

Unit 5: Hydraulic Modeling: Basic principles of similarity, dimensional analysis, non-dimensional modelling of free-surface flows, design of physical models. **(7L)**

References:

1. Novak, P. and Nalluri, C., "Hydraulic Structures", Edition 4, Taylor & Francis. 2007
2. Singh, B., and Varshney, R.S., "Embankment Dam and Engineering", Nem Chand and Brothers. 2004
3. USBR, Design of Gravity Dams, A Water Resources Technical Publication, Denver, Colorado, 1976.
4. Irrigation Water Resources and Hydropower Engineering, Modi, P. M., Standard Book Publishing Company, New Delhi, 9th Edition, 2014
5. Water Resources Engineering, Garg, S.K., Khanna publishers, Delhi, 1973.

Course code: CE22XXX	Hydropower Engineering	Credits 3 - 1 - 0: 4

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to

CO1	Understand hydropower systems, and analyze hydropower potential.
CO2	Analyze different types of hydropower plants.
CO3	Design components of hydropower plant such as penstocks, intakes and trash racks.
CO4	Evaluate types of turbines.
CO5	Design surge tank for prevention of water hammer.

Course Contents:

Unit 1: Introduction to Hydropower Systems: sources of energy, role of hydropower in a power system, estimation of hydropower potential: flow duration curves of gauge and ungauged streams, load curve, load duration curve, firm power, secondary power, prediction of load. **(8L)**

Unit 2: Types of Hydropower Plants: Runoff river plants, general arrangement of runoff river plants, valley dam plants, diversion canal plants, high head diversion plants, storage and pondage, pumped storage power plants, micro power plants. **(7L)**

Unit 3: Penstocks: Classification of penstocks, economical design of penstocks, losses, anchor blocks, valves, bends and manifolds. Intakes: types, losses, air entrainment, anti-vortex device, air vent, power channels, forebay, tunnel, Trash racks: types, losses, design, stability **(8L)**

Unit 4: Turbines: Introduction, types of turbines, hydraulics of turbines, draft tubes, cavitation in turbines, turbine model testing, characteristics of turbines, selection of turbine. **(8L)**

Unit 5: Water Hammer and Surges: Introduction, water hammer, transients caused by turbine, load acceptance and rejection, resonance in penstocks, channel surges. Surge Tanks: Functions, types of surge tanks, design of surge tanks, stability of surge tanks. **(6L)**

References:

1. H K Barrows, Water Power Engineering, McGraw Hill Book Co., New York., 1943.
2. Dandekar and Sharma, Water Power Engineering, Vikas Publishing House, New Delhi, 1996.
3. M M Deshmukh, Water Power Engineering, Dhanpat Rai Publications, New Delhi, 1998.
4. N C Nigam, Handbook of Hydro-power engineering, publishers Nem Chand and sons, Roorkee, 1999

5. R K Sharma and T K Sharma, Water Power Engineering S.CHAND & Company, New Delhi, 2003.
6. R S Varshney, Hydropower Structures, Nem chand and Bros., Roorkee (U.P.), 1992.
7. Guthrie Brown, Hydropower Electric Engineering, Blacki and Son, London, 1958.

Course code: CE22XXX	**Dams and reservoirs**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to

CO1	Understand planning for water resources projects.
CO2	Analyze forces acting on a gravity dam, failure modes, and stability.
CO3	Evaluate earth dam design, and seepage analysis.
CO4	Analyze reservoir planning and operation principles.
CO5	Understand and design hydroelectric power systems.

Course Contents:

Unit 1: Planning of water resources engineering project: Planning and investigations of reservoir and dam sites, choice of dams, preparation and protection of foundation and abutments. **(7L)**

Unit 2: Types of dams and their characteristics: Gravity dams, forces acting, method of analysis, modes of failure and factors of safety, elementary profile of a gravity dam, stability analysis, galleries. **(7L)**

Unit 3: Earth dam: Foundation, materials, criteria for safe design, typical sections, compaction of rock fill dam, seepage analysis. construction on permeable foundations, seepage theories, Khosla's theory, design of dams and other structures on permeable foundations. **(10L)**

Unit 4: Reservoirs, selection of dam sites, investigation, estimation of storage capacity, principle of reservoir planning, flood routing, reservoir loss, reservoir sedimentation. physical constraints on reservoir operations, reservoir operating rules, operating multi-reservoir systems, real-time operation, operation with uncertainty, trends in reservoir operation design. **(8L)**

Unit 5: Water Power: Assessment of potential, classification of power plants, penstocks, intakes, trash racks, types of turbine, power house. **(8L)**

References:

1. Peterka, A.J, "Hydraulic Design of Stilling Basins and Energy Dissipators", USBR Engineering Monographs No. 25". 1984

2. Singh, V.P. Handbook of Applied Hydrology, Second Edition, McGraw-Hill Education, 2017.
3. "Design of Small Dams", Third Edition, Water Resources Technical Publication – US Bureau of Reclamation. 1987
4. Singh, B., and Varshney, R.S., "Embankment Dam and Engineering", Nem Chand and Brothers. 2004
5. Chanson, H., "The Hydraulics of Open Channel Flow : An Introduction", Elsevier Scientific Publications. 2004
6. Novak, P. and Nalluri, C., "Hydraulic Structures", Edition 4, Taylor & Francis. 2007
7. Creager, Justin and Hinds, "Engineering for Dams", Vol. I and II, John Wiley
8. Water Resources Systems Planning and Management, Jain, S.K. and Singh, V.P., Elsevier Science, 2003.

Course code: CE22XXX	**Irrigation and drainage works**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to

CO1	Understand crop water requirements and methods of irrigation.
CO2	Design non-erodible canals for irrigation water supply.
CO3	Evaluate types of canal regulators and outlets.
CO4	Design anti-waterlogging measures and lined channels.
CO5	Design strategies for effective surface and subsurface drainage systems.

Course Contents:

Unit 1: Introduction, objectives of irrigation, selection of irrigation method and suitability. Irrigation requirement, water balance, soil water relationships, water storage zone, infiltration, flow of moisture through root zone, crop consumptive use requirements, irrigation efficiency, Surface irrigation systems, types of surface irrigation systems, basin irrigation, border irrigation, furrow irrigation, sprinkler and drip irrigation. **(10L)**

Unit 2: Classes of irrigation canal, parts of a canal system, preliminary survey, detailed survey, commanded areas, channel alignment, curves, assessment of water requirement, channel losses, Kennedy's theory, Lacey's theory, longitudinal section, schedule of area statistics and channel dimension cross- section of irrigation channel. **(8L)**

Unit 3: Canal regulation works and outlets: Falls, classification of falls, design of falls, distributary head regulator and cross-regulator, escape, bed bars. necessity and types, aquaduct, syphon aquaduct, super passage, canal syphon, level crossing, design of cross drainage work requirement and classes of outlets, non-modular outlet, semi-module, rigid module, selection of outlet. **(8L)**

Unit 4: Water logging definition, effect, causes and anti-water logging measure, concrete lining, shotcrete lining, asphaltic lining, brick tile lining of earth material, sections of lined channel. **(6L)**

Unit 5: Drainage principles, need for drainage, types of drains, surface and subsurface drainage, environmental considerations, pipe network layout and elevations, drainage sumps and pumps, steady state equations, Hooghoudt, Kirkham, Dagan and Ernst equations. **(8L)**

References:

1. Walker, W.R., and Skogerboe, G.V., "Surface Irrigation Theory and Practice", Prentice Hall, INC. 1987
2. Waller, P. and Yitayew, M. Irrigation and Drainage Engineering, Springer International Publishing, 2015.
3. Drainage Principles and Applications, "International Institute for Land Reclamation and Improvement", Wageningen. 1973
4. Michael, A.M., "Irrigation: Theory and Practice", Vikas Publishing House. 1978
5. Asawa, G.L., "Irrigation Engineering", New Age International Publishers. 1996
6. Majumdar, D.K., "Irrigation Water Management", PHI Learning. 2009
7. Luthin, J.N., "Drainage Engineering", John Wiley. 1966

Course code: CE22XXX	**Hydrometeorology**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to

CO1	Understand the hydrological cycle..
CO2	Evaluate models for precipitation and evapotranspiration.
CO3	Understand characteristics of snow and ice movement.
CO4	Design measurement techniques and instrumentation for precipitation and snow.
CO5	Apply forecasting techniques for precipitation, flood, and drought occurrences.

Course Contents:

Unit 1: Hydrological cycle, processes in hydrological cycle, global influences, water balance, impact of aerosols on the hydrological cycle, coupled models for hydrological cycle. **(6L)**

Unit 2: Equation of state for a perfect gas, hydrostatic pressure law, first law of hydrodynamics, growth of precipitation particles, precipitation systems, global

atmospheric circulation, modelling evaporation and transpiration, estimation of large-scale evapotranspiration **(8L)**

Unit 3: Snow and Ice: formation of snow and ice, characteristics of snow cover, glaciers, physics of melting and water movement through snow, modelling snowmelt and stream flow, snow avalanches. **(7L)**

Unit 4: Measurements and instrumentation: point measurement of precipitation, areal measurements, radar measurements of rainfall, measurement of snow, satellite based remote sensing. **(7L)**

Unit 5: Forecasting: precipitation forecasting, mesoscale models, data assimilation, medium range and seasonal forecasting, flood forecasting model development, probabilistic flood forecasting, modelling the occurrence of droughts, flood and drought frequency analysis. **(10L)**

References:

1. Rakecha, Singh, 2009. Applied Hydrometeorology, Capital publishing Company.
2. Collier, C.G. 2016. Hydrometeorology, Wiley
3. Sene, K. 2009. Hydrometeorology, Springer.
4. Bruce, J.P. and Clark, R.H. 2013. Introduction to Hydrometeorology, Elsevier Science.
5. Engineering Hydrology, Subramanya, K and Sharma,P.K, Tata McGraw Hill Publications, 2024 6th Edition

ELECTIVE-VI

Course code: CE22358	Environmental Impact Assessment	Credits 3 - 1 - 0: 4

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to

CO1	Understand EIA processes, screening, and scoping at regional and sectoral levels.
CO2	Analyze rapid and comprehensive EIA, legal frameworks, economic valuation, and GIS applications.
CO3	Evaluate legislative and environmental clearance procedures, CRZ regulations, and public participation.
CO4	Apply EIA methodologies for various environments.
CO5	Design environmental management plans, monitoring, audits, and EIA reporting.

Course Contents:

Unit 1: Overview of EIA, EIA at different levels: Regional, policy, sector levels, EIA process, screening and scoping criteria. **(6L)**

Unit 2: Rapid and comprehensive EIA, legal and regulatory aspect in India, environmental risk analysis, economic valuation methods, cost-benefit analysis, expert system and GIS applications, uncertainties. **(7L)**

Unit 3: Legislative and environmental clearance procedures in India and other countries, siting criteria, CRZ, public participation, resettlement and rehabilitation Plans. **(7L)**

Unit 4: Applications: Practical applications of EIA, EIA methodologies, baseline data collection, prediction and assessment of impacts on physical, biological and socio-economic environment. **(7L)**

Unit 5: Environmental management plan, post project monitoring, environmental audit, EIA report and EIS, review process. Case studies on EIA projects and environmental management plan. **(10L)**

References:

1. Canter, L.W., "Environmental Impact Assessment," McGraw Hill, New York, 1996.
2. Petts, J., "Handbook of Environmental Impact Assessment Vol. I and II ", Blackwell Science, London, 1999.
3. The World Bank Group, "Environmental Assessment Sourcebook Vol. I, II and III ", The World Bank, Washington, 1991.
4. Raman, N.S., and Gajbhiye, A.R. "Environmental Impact Assessment", TechSar Pvt. Ltd., 2014.
5. Bhateria et al. Environmental Impact Assessment, Springer, 2024.

Course code: CE22301	Optimization Methods in Civil Engineering	Credits 3 - 1 - 0: 4

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to

CO1	Understand basic concepts and applications of optimization.
CO2	Apply simplex methods for linear programming in civil engineering.
CO3	Evaluate non-linear optimization methods for one-dimensional variable problems.
CO4	Analyze unconstrained and constrained non-linear optimization techniques.
CO5	Design optimization solutions using genetic algorithms and ANN.

Course Contents:

Unit 1. Introduction: Historical development, engineering applications of optimization, statement of an optimization problem, classical optimization techniques. **(6L)**

Unit 2. Linear Programming: Simplex method and revised simplex method for linear programming problems, application of linear programming to civil engineering problems. post optimality analysis. **(8L)**

Unit 3. Non-Linear Programming: Optimization of one-dimensional variable problems by various methods. **(7L)**

Unit 4. Unconstrained and constrained optimization problems of nonlinear programming methods. **(6L)**

Unit 5. Genetic algorithm & ANN and their application in optimization. **(8L)**

References:

1. Optimization Methods for Engineering Design – R.L.Fox, Addison-Wesley, 1971.
2. Optimization Techniques, Theory and applications – S.S.Rao, Wiley, 1978.
3. Introduction to Dynamic Programming – L.Cooper & M.W.Cooper, Pergamon Press, 1981.
4. Non-Linear programming: Sequential Unconstrained Minimization Techniques- A.V.Fiacco & G.P.McCormic, Wiley, 1968.
5. Geometric Programming – Duffin, Peterson & Zenar, Wiley, 1967.
6. Foundation of Optimization – J.D.Wilde & C.L.Beightler, Prentice-Hallm 1967.
7. An introduction to OR – H Taha, Pearson, 2016.

Course code: CE22357	Groundwater Contamination and Pollution Transport	Credits 3 - 1 - 0: 4

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to

CO1	Understand groundwater as a resource.
CO2	Analyze the hydrologic cycle, flow-net construction, and flow models.
CO3	Evaluate aquifer testing, and artificial recharge techniques.
CO4	Understand chemical properties and processes in groundwater.
CO5	Evaluate models for solute transport and groundwater contamination.

Course Contents:

Unit 1: Introduction: Ground water as a resource, ground water contamination, , ground water and geologic processes. physical properties and principles, darcy's law, hydraulic head and flow potential, piezometers and nests. hydraulic conductivity and permeability, homogeneity and anisotropy, porosity and voids ratio, unsaturated flow and the water table, steady state flow and transient flow compressibility and effective stress, transmissivity , equations of ground water flow, limitations of Darcy's approach, hydro dynamic dispersion. **(8L)**

Unit 2: Hydrologic Cycle and Flow, net: Ground water and hydrologic cycles, flow nets, graphical construction, flow nets by numerical simulation, steady state regional ground water flow, steady state hydrologic, budgets, fluctuations in ground water levels. modelling principles and software. modelling principles, 1D, 2D, and 3D modelling, MOC modelling, USGS, MOC MODEL, Visual MODFLOW. **(10L)**

Unit 3: Resource Evaluation: Development of ground water resources, exploration for aquifers, the response of ideal aquifers to pumping, measurement of parameters , laboratory tests, piezometer test, pumping tests, estimation of saturated hydraulic conductivity, numerical simulation for aquifer yield prediction, artificial recharge and induced infiltration, land subsidence, sea water intrusion. **(7L)**

Unit 4: Chemical Properties and Principles: Constituents, chemical equilibrium, association and dissociation of dissolved species, effects of concentration gradients, mineral dissolution and solubility, oxidation and reduction process, ion exchange and adsorption, environmental isotopes, field measurement of index parameters. chemical evolution: hydro chemical facies, ground water in carbonate terrain, ground water in crystalline rocks, ground water in complex sedimentary systems, geochemical interpretation of 14c dates, process rates and molecular diffusion. **(7L)**

Unit 5: Solute Transport: Water quality standards, transport process, non, reactive constituents in homogeneous media and heterogeneous media, transport in fracture media, hydro, chemical behaviour of contaminants, trace metals, nitrogen, trace non, metals organic substances, measurement of parameters, velocity, dispersivity, chemical

partitioning, sources of contamination, land disposal of solid wastes, sewage disposal on land. **(6L)**

References:

1. Charbeneau, Randall J. "Ground Water Hydraulics and Pollutant Transport", Waveland Press Inc., USA, 2000.
2. Freeze, Allen R. and Cherry, John A. "Ground Water ". Prentice Hall Inc., 1979.
3. Todd, D. K., Ground water Hydrology, John Wiley & Sons, New York, 1995
4. Bear, J. and Cheng, A.H.D. Modelling Groundwater Flow and Contaminant Transport, Springer, 2010.
5. Zheng, C. Bennett, G., Applied Contaminant Transport Modelling, Wiley, 2002.

Course code: CE22XXX	**Hydrogeology**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE
Course Outcomes: At the end of the course, the student will be able to

CO1	Understand hydrological components, aquifers, and the hydrogeology of India.
CO2	Analyze groundwater quality, pollution issues, and treatment methods for arsenic and fluoride.
CO3	Apply well hydraulics and flow theories for confined and unconfined aquifers.
CO4	Evaluate permeability and aquifer parameters using various estimation methods.
CO5	Analyze groundwater management strategies and legislation.

Course Contents:
Unit 1: Hydrological Components, vertical distribution of groundwater, types of aquifers, springs, hydrogeological properties of water-bearing materials, groundwater level and its fluctuations, water table contour maps, groundwater basin, classification of rocks with respect to their water bearing characteristics, introduction to hydrogeology of india and the groundwater provinces of india. **(8L)**

Unit 2: Groundwater Quality: Physical and chemical properties of water, quality criteria for different uses, graphical presentation of water quality data. groundwater pollution, water quality problems of India, problem of arsenic and fluoride and remedial measures for their treatment. environmental isotopes and their application in hydrogeological studies. **(7L)**

Unit 3: Water Well and Well hydraulics: Well types, drilling methods, construction design, development and maintenance of wells, Darcy's law and its applications, theory of groundwater flow, numerical solutions for steady and unsteady state groundwater flow in confined and unconfined aquifers. **(7L)**

Unit4: Methods of permeability estimation in laboratory and field. Evaluation of aquifer parameters of confined aquifer using Theis, Thiem, and Jacob methods. Ground water exploration: Geophysical methods for groundwater exploration, application of geophysical methods: aquifer characterization, fracture zones and caves, saltwater intrusions, vulnerability of aquifers, mapping of contaminants. **(7L)**

Unit 5: Groundwater Management: Problem of overexploitation, water management in rural and urban areas, artificial recharge of water, consumptive and conjunctive use of surface and ground water, coastal area groundwater and its management, groundwater management in arid and semi-arid zone, groundwater in hard rocks and non-indurated sediments – their management, ground water legislation. **(8L)**

References:

1. Hiscock, K.M. and Vense, V.F. Hydrogeology, Wiley, 2021.
2. LaMoreaux, P. E. et al. Environmental Hydrogeology, CRC Press, 2008.
3. Rao, N.S. Hydrogeology: Problems with Solutions, PHI Learning Private Ltd, 2016.
4. Fetter, C.W. Applied Hydrogeology, Merrill Publishing Company, 1988.
5. Engineering Hydrology, Subramanya, K and Sharma,P.K, Tata McGraw Hill Publications, 2024 6th Edition

Course code: CE22XXX	**Oceanography**	**Credits 3 - 1 - 0: 4**

Pre-Requisites: NONE

Course Outcomes: At the end of the course, the student will be able to

CO1	Understand the equation of state for seawater, ocean stratification, and mixing dynamics.
CO2	Analyze equations of motion, and geostrophic flow in ocean circulation.
CO3	Evaluate major ocean currents.
CO4	Understand meridional overturning circulation, and the influence of topography.
CO5	Apply concepts of waves, tides, and coastal processes.

Course Contents:

Unit 1: The Equation of state of seawater, potential temperature, stability, some consequences of a stratified ocean, T-S diagrams, global heat balance, global water and salt balance, mixing, turbulence, and diffusion, box models and mixing times. **(7L)**

Unit 2: Equations of motion: Acceleration, pressure gradient, coriolis force, gravity: equal potential surfaces, friction, effect of earth's rotation, vorticity, Rossby number, geostrophic flow, Margule's equation, the general circulation. **(7L)**

Unit 3: Western Boundary Currents: The Gulf Stream and Kuroshio, Eastern Boundary Currents: The California Current System, Equatorial Currents, El Niño Southern Oscillation, Antarctic Circumpolar Current, Currents of the Indian Ocean. **(6L)**

Unit 4: Meridional overturning circulation and core analysis, the mediterranean outflow, basins and sills: the role of bottom topography in determining temperature and salinity distributions, formation of water types (water masses), vertical mixing, mesoscale eddies. **(7L)**

Unit 5: Tsunami, seiches, edge waves, very long waves: the coriolis effect, internal waves, tidal forces, equilibrium and dynamic theory of tides, ocean tides, tidal currents, estuarine circulation, estuarine residence time, coastal processes, semi-enclosed seas. **(10L)**

References:

1. Descriptive Physical Oceanography An Introduction By George L. Pickard, William J. Emery, 2013
2. Descriptive Physical Oceanography An Introduction By Lynne D. Talley, 2011
3. Introduction to Physical Oceanography By John A. Knauss, 2005
4. Reeve, D., Chadwick, A., and Fleming, C. 2018. Coastal Engineering: Processes, Theory and Design Practice. Taylor&Francis Group.
5. Sorensen, R. 2013. Basic Coastal Engineering, Springer US.