COURSE STRUCTURE AND SYLLABUS

of

Master of Technology
in
Water Resources Engineering

Effective from Session 2023-2024

DEPARTMENT OF CIVIL ENGINEERING
SCHOOL OF ENGINEERING AND TECHNOLOGY
CENTRAL UNIVERSITY OF JHARKHAND, BRAMBE,
RANCHI – 825 205, JHARKHAND

First Semester

Sl. No	Course Title		Periods Per Week			Credit
			L	T	P	
1.	Advance Hydrology	WRE 611011	2	1	0	3
2.	Open Channel and Fluvial Hydraulics	WRE 611021	2	1	0	3
3.	Advanced Numerical Methods	WRE 611031	2	1	0	3
4.	**Elective – I**		**2**	**1**	**0**	**3**
	Stochastic Hydrology	WRE 616011	2	1	0	3
	Flood forecasting and flood hazard management	WRE 616021	2	1	0	3
5.	**Elective – II**		**2**	**1**	**0**	**3**
	Design of Hydraulic Structures	WRE 616031	2	1	0	3
	Economics of Water Resources Planning	WRE 616041	2	1	0	3
6.	**Elective – III**		**2**	**1**	**0**	**3**
	Groundwater Hydrology	WRE 616051	2	1	0	3
	Design of Water Supply and Sewerage Systems	WRE 616061	2	1	0	3
	Water Law, Policies and Auditing	WRE 616071				
7.	Research Methodology and IPR	WRE 611141	2	0	0	2
8.	Hydrologic Design Lab	WRE 612111	0	0	2	1
9.	AU (Stress Management by Yoga)	AUD 616 121	2	0	0	0
10.	Seminar I	WRE 613131	0	0	1	1
		Total Credits				22

Second Semester

Sl. No	Course Title		Periods Per Week			Credit
			L	T	P	
1.	Advanced Fluid Mechanics	WRE 621 011	2	1	0	3
2.	Advanced Irrigation and Drainage Engineering	WRE 621 021	2	1	0	3
3.	**Elective – IV**		**2**	**1**	**0**	**3**
	Urban Water Management	WRE 626 011	2	1	0	3
	Climate Change Impact on Water Resources	WRE 626021	2	1	0	3
	Water Resources Systems Planning and Management	WRE 626031	2	1	0	3
5.	**Elective – V**		**2**	**1**	**0**	**3**
	Earth and Rock fill Dam	WRE 626041	2	1	0	3
	Application of Soft Computing Techniques	WRE 626051	2	1	0	3
	Isotope Hydrology	WRE 626061				
6.	**Elective – VI**		**2**	**1**	**0**	**3**
	Sediment Transportation	WRE 626071	2	1	0	3
	Hydrologic Systems Modelling	WRE 626081	2	1	0	3
	Hydropower Engineering	WRE 626091				
7.	**Elective - VII**		**2**	**1**	**0**	**3**
	Watershed Management	WRE 626101	2	1	0	3
	River Engineering	WRE 626111	2	1	0	3
8.	Advanced Irrigation and Drainage Engineering Lab	WRE626121	0	0	3	1
9.	Mini Project	WRE624131	0	0	4	2
10.	AU (Disaster Management)	AUD626141	2	0	0	0
		Total Credits				21

Third Semester

Course Title		Periods Per Week			Credit
		L	T	P	
Dissertation Phase I	WRE714011	0	0	32	16
Total Credits					16

Fourth Semester

Course Title	Course code	Periods Per Week			Credit
		L	T	P	
Dissertation Phase II	WRE724011	0	0	32	16
Total Credits		-	-	-	16

Summary				
Semester	**I**	**II**	**III**	**IV**
Semester-wise Total Credits	**22**	**21**	**16**	**16**
Total Credits	**75**			

Syllabus

First Semester

Course Code	**:**	**WRE 611011**
Course Title	**:**	**Applied Hydrology**
Number of Credits	**:**	**3 (L: 2, T: 1, P: 0)**
Course Category	**:**	**Professional Core Course**

Course Objective: The course aims to establish a strong foundation in engineering hydrology and enable the effective application of technical expertise in subjects such as hydrology and groundwater hydrology. It covers essential concepts including precipitation, infiltration, evaporation, runoff, hydrograph analysis, statistical methods, channel behaviour, and flood routing. The goal is to utilize this knowledge to solve various engineering challenges.

Course Content:

Unit	Content	Hours
I	Parameter Estimation: Method of Moments for continuous and discrete system, Method of L-moments, Method of Least Squares, Linear Regression: Goodness of regression, Multiple Linear Regressions: Estimation of Regression Coefficients, Inference on regression coefficients	**15**
II	Frequency Analysis: Return period, Hydrologic data series, Extreme value distribution, Frequency analysis using frequency factor, Probability plotting, Water resources council method, Testing of outliers, Reliability analysis.	**10**
III	Lumped flow routing: Lumped system routing, Level pool routing, Runge-Kutta method, Hydrologic river routing, Liner reservoir model. Distributed flow routing: Saint-Venant equations, Classification of distributed routing models, Wave motion, Analytical solution of the kinematic wave, Finite-difference approximation, Numerical solution of kinematic wave	**15**
IV	Dynamic Wave Routing: Dynamic stage-discharge relationship, Implicit dynamic wave model, finite difference equation, DWOPER model, Flood routing in meandering river, Dam break flood routing.	**5**

Recommended Books/References

1. K. Subramaya, Engineering Hydrology, Tata McGraw Hill Pub, New Delhi.
2. V.T. Chow, David R. Maidment, Larry W. MaysApplied Hydrology, McGraw Hill Education (India) Pvt. Limited, 2010.
3. R. S. Varshney, Engineering Hydrology, Nem Chand & Bros., Roorkee
4. Linsley, Kohler and Paulhus, Hydrology for Engineers, McGraw Hill International Co.
5. B. L. Gupta, Engineering Hydrology, Standard Publishers and Distributors, New Delhi

Course Outcomes: The students shall learn to

- Describe the basic concepts of parameter estimate and integrate the physical hydrological processes.
- Describe the various routing processes

Course Code	**:**	**WRE611021**
Course Title	**:**	**Open Channel and Fluvial Hydraulics**
Number of Credits	**:**	**3 (L:2,T:1, P:0)**
Course Category	**:**	**Professional Core Course**

Course Objective: To understand the different types of open channel flows, forces acting in open channel flow and its applications.

Course Content:

Unit	Content	Hours
I	Basics of free surface flows, velocity and pressure distribution, Uniform Flow, Concept of specific energy, specific force, critical flow, critical depth.	**10**
II	Gradually Varied Flow (GVF); Governing Equation of gradually varied flow and its limitations, flow classification, surface profiles and its characteristics, Control sections, Computation methods and analysis: analytical, graphical and advanced numerical methods.	**10**
III	Rapidly Varied Flow (RVF); Characteristics of rapidly varied flow, Hydraulic jump, types of jump, basic characteristics of jump, length and location of jump, jump as energy dissipation, control of jump, surges, surge channel transitions. Rapidly varied unsteady flow: Equation of motion for unsteady flow, "Celerity" of the gravity wave, deep and shallow water waves, open channel positive and negative surge,	**10**
IV	Spatially Varied Flow (SVF); Basic principles, Differential SVF equations for increasing and decreasing discharge, Classifications and solutions, Numerical methods for profile computation, Flow over side-weir and Bottom-rack.	**10**
V	Flow through non-prismatic channel sections, sudden transition, sub-critical flow through sudden transition, flow through culverts, obstructions, and channel junction.	**5**

Recommended Books/References

1. V. T. Chow, Open Channel Hydraulics, McGraw-Hill International Book Co., Singapore, 1973.
2. K. Subramanya, Flow in Open Channels, Tata McGraw Hill, 2009.
3. K.G. Ranga Raju, Flow through open channels, T.M.H, 1993.

Course Outcomes: After successful completion of this course, the students will learn:

- Computation of Uniform flow and critical flow

- Concepts, computation and application of gradually varied flow, rapidly varied flow and spatially varied.

Course Code	**:**	**WRE611031**
Course Title	**:**	**Advance Numerical Methods**
Number of Credits	**:**	**3 (L: 2, T: 1, P: 0)**
Course Category	**:**	**Professional Core Course**

Course Objective: To familiarize the prospective engineers with techniques in equations. It aims to equip the students to deal with advanced level of mathematics and applications that would be essential for their disciplines.

Course Content:

Unit	Content	Hours
I	Polynomials, Lagrange interpolating polynomials, spline interpolation, Newton's Forward, Backward and Central Difference formula, Sterling's formula.	**10**
II	Numerical differential and Integration Newton-Cotes integration formulas: Trapezoidal rule, Simpson's rule, integration with unequal segments, open integration formulas, Integration of equations: Romberg integration, Gauss Quadrature, improper integrals. Numerical Differentiation: High- Accuracy Differentiation formulas, Richardson extrapolation, Derivatives of unequally spaced data.	**15**
III	Ordinary Differential equations: Euler's method, modification and improvements of Euler's method, Runga Kutta methods, Taylor's series method, boundary value problems. Partial Differential Equations: Finite Difference — Elliptic equations; Laplace equation; Parabolic equation, explicit method, implicit method, Crank — Nicolson method, Parabolic equations in two spatial dimensions.	**15**
IV	Applications of Numerical analysis and its code	**5**

Recommended Books/References

1. S. S. Sastry, Numerical Analysis, Prentice Hall India (Latest Edition), 2015.
2. G. Sankar Rao, Numerical Analysis, New Age International Publishers, New Hyderabad, 2006.
3. H.C Saxena, Finite Differences and Numerical Analysis, S. Chand and Company, Pvt. Ltd., New Delhi.2009.
4. M. K. Jain, S.R.K.Iyengar, R.K. Jain, Numerical methods for scientific and engineering computation, NEW AGE, 2012.
5. B. S. Grewal, Numerical Methods in Engineering and Science with Programs in C, C++ & MATLAB, Khanna Publishers; Eleventh edition, 2013.

Course Outcomes: The students shall learn

- Basic knowledge in solving interpolation with equal interval problems by various numerical methods. Estimate the missing terms through interpolation methods.
- To find the derivatives using Newton's forward difference formula, Newton's backward difference formula, Derivatives using central difference formulae, Stirling's interpolation formula, Newton's divided difference formula, Maximum and minimum values of a tabulated function.
- Use relevant numerical techniques to code in numerical methods in a modern computer language.

Course Code	**:**	**WRE 616011**
Course Title	**:**	**Stochastic Hydrology**
Number of Credits	**:**	**3 (L: 2, T: 1, P: 0)**
Course Category	**:**	**Professional Elective Course**

Course Objective: The objective of this course is to introduce the concepts of probability theory and stochastic processes with applications in hydrologic analysis and design.

Unit	Content	Hours
I	Deterministic and Stochastic Hydrology, Probability axioms, Random variables and their properties, Probability distribution and probability density function, Continuous and Discrete distributions	**15**
II	Moments and expectations of distributions, Parameter estimation, Analysis of hydrologic extremes, Frequency analysis, Regional flood frequency analysis	**15**
III	Transformations, Hypothesis Testing, Goodness test of fit tests, Chi Square test and KS test, Multivariate regression analysis, Correlation coefficient and its significance in regional analysis, Modelling hydrologic uncertainty	**5**
IV	First order Markov process, Markov chain, Data generation, Hydrologic Time Series Analysis, Modelling of Hydrologic Time Series	**10**

Recommended Books/References

1. Charles T. Haan, Statistical Methods in Hydrology, East West Publishers, 1998.
2. N.T. Kotteguda, Stochastic Water Resources Technology, The Macmillan Press, New York, 1982.
3. R.H. McCuen, Hydrologic Analysis and Design, Prentice Hall Inc. N York, 2005.
4. N.T. Kotteguda and Renzo Resso, Statistics, Probability and Reliability for Civil and Environmental Engineers, McGraw Hill Companies Inc., New York, 1998.

Course Outcomes: Students would be equipped with methodologies of addressing uncertainties in hydrologic systems and one step ahead forecasting. Students will be able to:

- Statistically characterize water resources data;

- Perform a frequency analysis to estimate the magnitude of an event having a given frequency of occurrence or to estimate the frequency of occurrence of an event having a given magnitude;
- Analyze hydrologic time series by identifying the proper model, estimating the model parameters, verifying the assumptions of the model and generating synthetic series that resemble the data;
- Perform an analysis of spatially referenced data including the estimate of values at locations where measurements are not available and the estimate of the associated uncertainty.

Course Code	**:**	**WRE616021**
Course Title	**:**	**Flood Forecasting and Flood Hazard Management**
Number of Credits	**:**	**3 (L: 2, T: 1, P: 0)**
Course Category	**:**	**Professional Elective Course**

Course Objective: To learn the techniques of Flood foresting and to manage flood in such a way the flood hazard is minimum.

Course Content:

Unit	Content	Hours
I	Definition of flood, Precipitation pattern over the country. Theory of flash flood events, Estimation of Flood Peak, Design Flood Estimation, Guidelines for the Estimation of Design Flood for the Design of Cross Drainage Works, Concept of PMF	**10**
II	Flood Forecasting: Travel time, gage and discharge methods for flood forecasting. Flood Management and Remote Sensing Applications: Flood control planning, Flood plain mapping and zoning, Flood frequency analysis.	**10**
III	Flood analysis, Flood routing in channels and reservoirs: Muskingum Method of Channel Routing, Modified Pul's Method of Reservoir Routing, Real-time flood warning and flood forecasting, HEC-RAS Model and its use in Flood Forecasting, Application of HEC-RAS model for Flood management and planning, Flood Forecasting and Flood Protection.	**15**
IV	Flood Control Measures: Structural Measures, Non- Structural Measures, Flood Control Economics: Assessment of Flood Protection Costs and Benefits; Flood warning system	**10**

Recommended Books/References

1. M.C. Anderson, T.P. Burt, Manual on flood forecasting, New Delhi, 1985.
2. Central Water Commission, Hydrological forecasting, John Willy and Sons, 1989.
3. WMO, Automatic collection and transmission of hydrological observations, Operational Hydrology report no. 2, Geneva, Switzerland, 1973

Course Outcomes: The students after studying this will able to learn:

- The essential techniques used in flood forecasting and flood plain management

- The effective measures to reduce the impact of flood by using HEC-RAS and other measures

Course Code	**:**	**WRE616031**
Course Title	**:**	**Design of Hydraulic Structures**
Number of Credits	**:**	**3 (L: 2, T: 1, P: 0)**
Course Category	**:**	**Professional Elective Course**

Course Objectives: To impart knowledge on Analysis and Design Aspects of different Components of Hydraulic Structures and Irrigation and Drainage Systems.

Course Content:

Unit	Content	Hours
I	Design of Hydraulic structures on permeable foundation including weir and barrage, determination of afflux and discharge intensity, waterway and looseness factor, stilling basin level and length, uplift pressure and exit gradient, floor thickness and protection works.	**10**
II	Types of Dams, storage capacity, Reservoir planning, Gravity Dams-general features, forces acting on gravity dams, gallaries and their functions, stability analysis, roller compacted RCC dams.	**10**
III	Earth dams-homogeneous and zoned section, filter design and stability analysis. Spillways- layout and design of various types of spillways, design of energy dissipaters.	**10**
VI	Intake Structures-trash racks and their cleaning and handling devices; stop log arrangements, intake entrance, aeration vent, gate control. Tunnels-Classification, rock cover, hydraulic design and supporting systems; concrete lining; portals and plugs; underground cavities.	**10**
V	Gate- Various types of gates for barrages; spillways; intakes; sluices; structural design considerations for vertical lift and radial gates.	**5**

Recommended Books/References:

1. S. K. Garg, Irrigation Engineering and hydraulic structures, Khanna Publishers, 1976
2. P.N. Modi, Irrigation, water Resources and Water Power Engg, Standard Book House, Delhi-6, 2020
3. S. M. Challa. Water Resources Engineering Principle and practice, New Age Internation (P) Ltd. Publishers. New delhi, 2020
4. US Department of the Interior Bureau of Reclamation, Design of Small Dams, McGraw Hill,1987
5. R.S. Varsney, Concrete Danms, Oxford & I & H Publishing Co. New Delhi, 1978
6. R. S. Varshney, S. C. Gupta, Theory and Design of Irrigation Structures Vol I, 2009

7. R. S. Varshney, Theory and Design of Irrigation Structures Vol II Canal and Storage Works, 2007
8. B.C. Punmia, A. K. Jain, A. K. Jain, Irrigation and Water Power Engineering, 2009

Course Outcome: Students will be able to understand the Structural and Hydraulic Design of various components of hydraulic structures.

Course Code	**:**	**WRE616041**
Course Title	**:**	**Economics of Water Resources Planning**
Number of Credits	**:**	**3 (L:2, T:1, P:0)**
Course Category	**:**	**Professional Elective Course**

Course Objective: To impart the knowledge of existence, uses, rights and pricing of water, and needs and methods of economic evaluation of water resources systems.

Course Content:

Unit	Content	Hours
I	Introduction: Water availability and uses, surface and groundwater resources, water use practices, and challenges.	**10**
II	Water Rights and Sustainability: Principle, implementation and challenges of water rights, the Dublin statement, action agenda and viewpoints	**15**
III	Valuing and pricing of water: Economic value, use and non-use values, valuation and its methods, full value and losses, sustainable water pricing, setting water tariffs and water tariff models, reforms and conflicts.	**15**
IV	Economic Evaluation: Economic analysis, financial analysis, benefit-cost analysis, demand and sectoral allocation, methods of evaluation, and Governance.	**5**

Recommended Books/References

1. A. Dinar, and Y. Tsur, The Economics of Water Resources - A Comprehensive Approach, Cambridge University Press, 2021.
2. L. D. James and R. R. Lee, Economics of Water Resources Planning, McGraw-Hill Book Company, 2008.
3. S. Merrett, Introduction To The Economics Of Water Resources - An International Perspective, Taylor & Francis, 2004.
4. S. Merrett, The price of water: Studies in water resource economics and management, IWA Publishing, 2005.

Course Outcomes: Upon successful completion of the course, the students will be able to:

- Understand the various components and need of economics of water resources planning.
- Understand the issues and challenges and the legal and economic frameworks associated with water resources planning.

Course Code	**:**	**WRE616051**
Course Title	**:**	**Groundwater Hydrology**

Number of Credits	**:**	**3 (L: 3, T: 0, P: 0)**
Course Category	**:**	**Professional Elective Course**

Course Objective: The course aims to empower students with the skills needed to elucidate groundwater occurrences, categorize aquifers, and understand aquifer properties within diverse geological settings. Students will conduct thorough analyses of hydrological flow systems in groundwater contexts. They will also develop the ability to conduct in-depth groundwater balances, interpret concepts of recharge, storage, and discharge, and comprehend steady-state and transient groundwater flow processes. Application of analytical solutions for solving groundwater management issues will also be covered.

Course Content:

Unit	Content	Hours
I	Groundwater and Well Hydraulics: Steady unidirectional flow, Steady radial flow to a well, Unsteady radial flow in a confined aquifer, Unsteady radial flow in an unconfined aquifer, Unsteady radial flow in a leaky aquifer, Well flow near aquifer boundaries, Multiple well system, Partially penetrating wells, Well flow for special conditions.	**15**
II	Groundwater Resources Assessment: Geological /geophysical exploration/ remote sensing / electric resistivity /seismic refraction-based methods for surface investigation of ground water	**10**
III	Water Wells: Test holes and well logs, Methods of constructing shallow wells (Dug wells, Bored wells, Driven wells, Jetted wells), Methods for drilling deep wells, , Well completion, Well development, Testing wells for yield, Pumping equipment, Protection of wells, Well rehabilitation, Horizontal wells, Characteristic well losses, Specific capacity and well efficiency, Slug test, Slug test for confined formation, Slug test for unconfined formation	**10**
IV	Groundwater Flow Modelling Techniques: Development of groundwater flow models, Types of groundwater models, Steps in development of groundwater models, Simulation of two-dimensional groundwater systems-governing equations, finite difference approximation, solution, case study. Introduction to MODFLOW.	**10**

Recommended Books/References

1. D.K. Todd, L.W. Mays, Groundwater Hydrology, Wiley, 2004.
2. H.M. Raghunath, Ground Water, New Age International Publishers, 2007.
3. F. Schwarz, H. Zhang, Fundamentals of Ground Water, Wiley, 2002.
4. C. Fitts, Groundwater Science, Academic Press, 2012.
5. J. Bear, Hydraulics of Groundwater, Dover Publications, 2007.

Course Outcomes:

- Comprehend the basic concepts and techniques used in groundwater hydrology
- Understand how to gather and use information to apply the learned concepts outside of class
- Develop skills to approach complex problems that do not have a single correct answer
- Think critically, observe broadly, and apply educated judgement to make decisions

Course Code	**:**	**WRE616061**
Course Title	**:**	**Design of Water Supply and Sewerage Systems**
Number of Credits	**:**	**3 (L: 2, T: 1, P: 0)**
Course Category	**:**	**Professional Elective Course**

Course Objective:
This module introduces the fundamentals of Water Supply and Sewerage. The module will be dividing into a list of the lectures. It will start with water demand and population Forecasting. This will be provided the information about the amount of needed water for human and industry actives. The next lectures will be the water quality and water treatment. Then, the network pipe design will give the knowledge about the types and requirements to make a new network pipeline. The last lectures will be Sewerage design.

Course Content:

Unit	Content	Hours
I	Introduction to water supply and source of water, Estimate Water Demand, Population Forecasting, Water quality, water quality parameters, and water quality standards (WHO, BIS).	**10**
II	Water treatment, Water Intake structure, Water treatment: Coagulation and Flocculation, Sedimentation, Sedimentation tank Efficiency (for discrete settling), Filtration, Disinfection, Storage and pumping	**15**
III	Water supply system, pumping, elevated tank, and ground storage tank, Water Distribution system, types of Water Distribution system, Hydraulics of pipe flow, Pipe Network Analysis and Design, Hardy Cross method, Pipe fittings and Appurtenances, Construction of pipe lines	**10**
IV	Waste water and Sewerage, Wastewater Treatment: Primary treatment, secondary treatment, Collection of sewage water, estimate the amount of sewage, Manholes and storm-water inlets details and specifications, Design of sewer pipes, Drainage System in Buildings; Sanitary Fixtures, drain pipes, Vent Pipes, Design of drainage system	**10**

Recommended Books/References

1. Nazih K. Shammas and Lawrence K. Wang, Water Engineering: Hydraulics, Distribution and Treatment, 1st edn. John Wiley & Sons, Inc., 2015.
2. Subhash Verma, et. al, Water Supply Engineering. New Delhi, 2015.
3. S. R. Qasim, E.M. Motley and G. Zhu, WaterWorks Engineering: Planning. Design & Operation, PHI Learning Private Limited, New Delhi, 2011.
4. Mackenzie L. Davis, Water and Wastewater Engineering: Design Principles and Practice. McGraw-Hill Companies Inc., 2010.
5. P. K. Swamee, A. K. Sharma, Design of Water Supply Pipe Networks. John Wiley & Sons. Canada, 2008.
6. D. V. Chaderton, Building Services Engineering, 5th edn. Taylor & Francis, 2007

7. S. Kawamura, Integrated Design and Operation of Water Treatment Facilities, 2nd edn. John Wiley & Sons Inc., 2000.
8. E. W. Steel, Water Supply and Sewerage, 5th edn. McGraw-Hill, 1979.
9. Metcalf and Eddy, Wastewater Engineering: Treatment and Reuse, 2nd edn, McGraw-Hill, New York, 2003.

Course Outcomes: Upon successful completion of this course, students will be able to design in the following important fields:

- Design of various water treatment plant components,
- Design of various wastewater treatment plant components,
- Design of urban water distribution systems, storm and sewerage systems,
- Design of water, fire-fighting, sewerage and stormwater systems for buildings,
- Verifying Designs with the aid of software, such as EPANET.

Course Code	**:**	**WRE 616071**
Course Title	**:**	**Water Law, Policies and Auditing**
Number of Credits	**:**	**3 (L: 3, T: 0, P: 0)**
Course Category	**:**	**Professional Elective Course**

Course Objective: The main objective of this course is to increase knowledge about water law, polices, and auditing. After completing this course, participants will understand how policies are developed and what are stages of development of policies. Further, students will be taught how water auditing can improve decision making around water management and water governance.

Course Content:

Unit	Content	Hours
I	Water Law in India; An overview of water law in India - evolution of water law, key features of water law, evolving water law and policy, water sector reforms, water law reforms, the mosaic of water law.	**15**
II	National and International Framework for Water Law; Basic structure of water law - International water law documents directly relevant in India, human right to water. Basic topics of water law, including the fundamental right to water and the basic constitutional scheme for determining the jurisdiction over water, from the local to the national level. Basic principles and concepts of water law.	**15**
III	Government policies documents for drinking water in general and rural water supply. Policies for urban drinking water supply and irrigation, and details of existing legislation as well as policy documents proposing a new framework for water supply, to include a focus on cost recovery and the involvement of the private sector.	**15**

Recommended Books/References

1. Philippe Cullet and Sujith Koonan, Water Law in India- An Introduction to Legal Instruments, Oxford Scholarship, 2011.
2. Jeff Sturman, Goen Ho, Kuruvilla Mathew, Water Auditing and Water Conservation, IWA Publishing, 2004.

3. Slavko Bogdanovic, Water policy and law in the Mediterranean – an evolving nexus, Faculty of Law of the university business academy in Novi Sad, 2011.

Course Outcomes: The students will learn:

- Development of policies, stages of development
- How policies affect the water governance
- Various National Water Policies and a comparative study.

Course Code	**:**	**WRE611101**
Course Title	**:**	**Research Methodology and IPR**
Number of Credits	**:**	**2 (L: 2, T: 0, P: 0)**
Course Category	**:**	**Professional Core Course**

Course Objective: To impart knowledge on formulation of research problem, research methodology, ethics involved in doing research and importance of IPR protection

Course Content:

Unit	Content	Hours
I	Foundations of Research: Meaning, Objectives, Motivation, Utility. Concept of theory, empiricism, deductive and inductive theory. Problem Identification & Formulation: Research Question, Investigation Question, Measurement Issues, Hypothesis: Qualities of a good Hypothesis, Null Hypothesis & Alternative, Hypothesis Testing – Logic & Importance.	**10**
II	Research Design: Features of a good research design, Exploratory Research Design – concept, types and uses, Descriptive Research Designs – concept, types and uses. Experimental Design: Concept of Independent & Dependent variables. Qualitative and Quantitative Research: Qualitative research, Quantitative research, Model evaluation guidelines.	**10**
V	Interpretation of Data and Paper Writing – Layout of a Research Paper, Journals in Water Resources/Transportation Engineering, Impact factor of Journals, Ethical issues related to publishing, Plagiarism and Self-Plagiarism, Reference Management Software like Mendeley.	**5**
VI	Understanding basics of IPR, Types of patent application and claim construction, Patent search, Procedure and managements of patents, Assessment of new idea, its patentability and patent filing procedure	**5**

Recommended Books/References

1. Douglas C. Montgomery, Design and Analysis of Experiments, Willey, India, 2007.
2. C. R. Kothari, Research Methodology- Methods and Technique, New Age International, New Delhi, 2004.
3. Douglas C. Montgomery and George C. Runger, Applied Statistics and Probability for Engineers, Willey, India, 2007.
4. Stuart Melville and Wayne Goddard, Research Methodology: An introduction for Science & Engineering Students, Juta and Co. Limited, 1996.
5. Ranjit Kumar, Research Methodology: A Step by Step Guide for Beginners, Pearson India, 2nd Edition, 2005.

6. D. J. Halbert, Resisting Intellectual Property, Taylor & Francis Ltd, 2007.

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

- Understand research problem formulation & Analyze research related information and Follow research ethics
- Correlate the results of any research article with other published results. Write a review article in the field of engineering.
- Appreciate the importance of IPR and protect their intellectual property. Understand that IPR protection provides an incentive to inventors for further research work and investment in R & D, which leads to creation of new and better products, and in turn brings about, economic growth and social benefits
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Course Code	**:**	**WRE612111**
Course Title	**:**	**Hydrologic Design Lab**
Number of Credits	**:**	**1 (L: 0, T: 0, P: 2)**
Course Category	**:**	**Lab Course**

Course Objective: The objective of the Hydrologic Design Lab is to acquaint the students with the various tools in hydrology to determine with the help of available data. The student with get the knowledge of the different methods in hydrological analysis

Course Content:

Experiment No.	Content
1	Analysis of Precipitation Data, Construction of IDF curves Derivation of Unit Hydrograph
2	Estimation of Evaporation and Evapotranspiration, Determination of Yield from A Catchment,
3	Estimation of Design Flood, Regional Flood Frequency Analysis
4	Hydrologic and Hydraulic flood routing, Derivation of Synthetic Unit Hydrograph

Recommended Books/References

1. V.T. Chow, D.R. Maidment, and L.W. Mays, Applied Hydrology, Tata McGraw Hill Edition 2, 2000.
2. Warren Viessman, Jr. and G L Lewis, Introduction to Hydrology, Prentice Hall India Pvt. Ltd., New Delhi, 2002.
3. R.H. McCuen, Hydrologic Analysis and Design, Prentice Hall Inc. N York., 2005.

Laboratory Outcomes: The students will learn:

- To construct IDF curve with available rainfall data.
- To derive synthetic unit hydrograph in the class.

Course Code	**:**	**AUD616121**
Course Title	**:**	**Stress Management by Yoga**
Number of Credits	**:**	**0 (L:2, T:0, P:0)**
Course Category	**:**	**Audit Course**

Course Objective:
The main aim of this course is to teach students about stresses, their effects and different yoga/meditation techniques for reliving the stress of the body and mind.

Course Content:

Unit	Content	Hours
1	Meaning and Definition of Stress. Types: Eutress, Distress, Anticipatory Anxiety, Intense Anxiety and Depression. Meaning of Management – Stress Management.	**6**
2	Concept of Stress according to Yoga: Patanjali aphorism (PYS II - 3) Avidya Asmita. Bhagavad – Gita (Gita II 62-63) Dhayato Visayam Punsah, Yoga Vasistha and Upanishad.	**8**
3	Mechanism of Stress related diseases: Psychic, Psychosomatic, Somatic and Organic phase. Role of Meditation & Pranayama on stress – physiological aspect of Meditation. Constant stress & strain, anxiety, conflicts resulting in fatigue among Executive. Contribution of Yoga to solve the stress related problems of Executive.	**8**
4	Meaning and definition of Health – various dimensions of health (Physical, Mental, Social and Spiritual) – Yoga and health – Yoga as therapy. Physical fitness. Stress control exercise – Sitting meditation, Walking meditation, Progressive muscular relaxation, Gentle stretches and Massage.	**8**

Recommended Books/References

1. Andrews, Linda Wasmer., Stress Control for peace of Mind. London: Greenwich Editions, 2005.
2. Lalvani, Vimla., Yoga for stress. London: Hamlyn, 1998.
3. H.R. Nagendra, and R. Nagarathana, Yoga perspective in stress management. Bangalore: Swami Vivekananda Yoga Prakashana, 2004
4. H.R. Nagendra and R. Nagarathana, Yoga practices for anxiety & depression. Bangalore: Swami Sukhabodhanandha Yoga Prakashana, 2004.
5. Sukhabodhanandha, Swami, Stress Management. Banglore: Prasanna trust, 2002.
6. K.N. Udupa, Stress management by Yoga. NewDelhi: Motilal Banaridass Publishers Private Limited, 1996.

Course Outcome: After completion of this course, students will be able to

- Know about the different kind of stresses occurs in the individual.
- Know about the diseases occurs due to stresses developed in body and mind.
- Know about different kind of yoga/mediation for reliving the stresses.

Course Code	**:**	**WRE 613131**
Course Title	**:**	**Seminar I**
Number of Credits	**:**	**1 (L:0,T:0, P:2)**
Course Category	**:**	**Professional Core Course**

Course Objective:

1. Identify and compare technical and practical issues related to the area of WRE.
2. Prepare a well-organized report employing elements of technical writing and critical thinking.
3. Demonstrate the ability to describe, interpret and analyze technical issues and develop competence in presenting.

Course Outcome:

- Establish motivation for any topic of interest and develop a thought process for technical presentation.
- Organize a detailed literature survey and build a document with respect to technical publications.
- Analysis and comprehension of proof-of-concept and related data.
- Effective presentation and improve soft skills.

Second Semester

Course Code	**:**	**WRE 621011**
Course Title	**:**	**Advanced Fluid Mechanics**
Number of Credits	**:**	**3 (L:2, T:1, P:0)**
Course Category	**:**	**Professional Elective Course**

Course Objective: To impart the knowledge of concepts of fluid mechanics from both theoretical and applications perspective to the students. The students will have sufficient mathematical and physical background to formulate real life problems in fluid mechanics.

Course Content:

Unit	Content	Hours
I	Fundamental concepts and scope, Structure of Fluid Mechanics, Kinematics of fluid motion. Continuity equation, control volume approach. Reynolds Transport Theorem, Conservation laws, Potential Flow, Rotational and irrotational motion, circulation, vorticity, velocity potential and stream function, Laplace's equation, Dynamics of ideal fluids, Euler's equation of motion.	**15**
II	Viscous Laminar flow, derivation of Navier-stokes equations and their solutions for simple problems. Instability of Laminar flow. Theory of boundary layer, boundary layer approximations, Separation, Turbulent flow and Dimensional Analysis.	**12**
III	Diffusion and Dispersion of Pollutant in a Fluid Medium, Geophysical fluid dynamics - geostrophic flow, geostrophic balance. Discharge measurement techniques in open channels.	**10**
IV	Ordinary and partial differential equations; finite difference schemes - implicit and explicit types; method of characteristics.	**8**

Recommended Books/References

1. G. K. Bachelor, An introduction to Fluid Dynamics, Cambridge Univ. Press, 2002.
2. R.W. Fox, P. J. Pitchard and A. T. Mcdonald, Fluid Mechanics, Wiley India Pvt. Ltd., 2009.
3. J. O. Hintze, Turbulence, McGraw Hill, 1959.
4. Hunder Rose, Advanced Mechanics of Fluids, 1959.
5. H. Schlichting and K. Gresten, Boundary Layer theory, Springer Publications, 2004.
6. F.M. White, Viscous Fluid Flow, McGraw Hill Pub. Co, N York, 2011.
7. M. S. Yalin, Theory of Hydraulic Models, McMillan Co., 1971.

Course Outcomes: Upon successful completion of the course, the students will be able to:

- Get the basic knowledge of the applicability of physical laws and its problems in hydraulics.
- Gain the skills to take up research activities involving fluid motions

Course Code	**:**	**WRE621021**
Course Title	**:**	**Advanced Irrigation and Drainage Engineering**
Number of Credits	**:**	**3 (L:2,T:1, P:0)**
Course Category	**:**	**Professional Core Course**

Course Objective: to understand the basic concepts of irrigation, crop water requirement, irrigation efficiencies, design and evaluation of water application methods, efficient drainage and management of drainage water and salt affected land.

Course Content:

Unit	Content	Hours
I	Necessity of irrigation- scope of irrigation engineering- benefits and ill effects of irrigation- irrigation development in India- types of irrigation systems, Soil-water plant relationship: Classification of soil water- soil moisture contents- depth of soil water available to plants permanent and ultimate wilting point, Crop water requirement: Duty, delta base period, irrigation efficiencies, consumptive use, net irrigation requirement, frequency of irrigation; canal capacity, rotational delivery, conveyance and seepage losses.	**15**
II	Alignment- canal capacity- losses- FSL of canal- design of canal in alluvial soil and non-alluvial soils- Kennedy's silt theory- Lacey's regime theory- balancing depth- use of Garrets diagrams and Lacey's Regime diagrams- lining of irrigation channels- design of lined canal drainage behind lining. Water logging: Causes, Measures: surface and sub-surface drains, land reclamation	**10**
III	Diversion head works: Types- selection of the suitable site for the diversion headwork components of diversion headwork- Causes of failure of structure on pervious foundation- Khosla's theory- Design of concrete sloping glacis weir, Cross drainage works: Types- selection of suitable type of CD works- aqueduct and Syphon aqueduct- determination of maximum flood discharge and waterway for drain, fluming of canal- uplift pressure on underside of barrel roof and at the floor of the culvert- design of bank connections.	**10**
IV	Planning and Design of Irrigation Systems: Design and evaluation of surface irrigation systems, Volume balance surface irrigation system design, Land grading and earthwork calculations, Canal regulation works: Canal fall- necessity and location- types of falls- Cross regulator and distributory head regulator- their functions, Silt control devices, Canal escapes- types of escapes. Surface drainage and subsurface drainage, water logging, effect, causes and preventive measures, drainage water use, salt affected soil and salinity control.	**10**

Recommended Books/References

1. P.N. Modi, Irrigation Water Resources and Water Power Engineering, Standard Book House, New Delhi.

2. S.K. Garg, Irrigation Engineering and Hydraulic Structures, Khanna Publishers, New Delhi.
3. R.K. Sharma, Text book of Irrigation Engineering and Hydraulic Structures, Oxford and IBK Publishing House, New Delhi.
4. S.K. Sharma, Principles and Practice of Irrigation Engineering, S. Chand & Company Pvt. Ltd, New Delhi
5. B.C. Punmia and B.B. Pande, Irrigation and Water Power Engineering, Laxmi Publication Pvt. Ltd., New Delhi
6. A.M. Micheal, Irrigation, Theory and Practice, Vikas Publishing House Pvt. Ltd. New Delhi
7. Das and Saikia , Irrigation and Hydropower Engineering, PHI Lerning Pvt Ltd.
8. K.N Sharma, water Power Engineering, Vikas Publishing House

Course Outcomes: On the completion of the course one should be able to understand:

- Concepts of irrigation and different hydraulic structures.
- How to estimate the quantity of water required by crops?
- Be able to plan and design irrigation projects.
- Design channels and other irrigation structures required for irrigation, drainage, soil conservation, flood control and other water-management projects.

Course Code	**:**	**WRE626011**
Course Title	**:**	**Urban Water Management**
Number of Credits	**:**	**3 (L: 2, T: 1, P: 0)**
Course Category	**:**	**Professional Elective Course**

Course Objective:

To learn the techniques of managing urban water this includes supplying water for urban consumption and role of climate change in urban water availability

Course Content:

Unit	Content	Hours
I	Urban water management system; Need of urban water management system and its effect due to climate change. Urban water economics. Urban water quality parameters: Physical, chemical and biological parameters of natural water bodies like lake, river and estuary; Water quality standards, Eutrophication; Sources of pollution, mass bathing impacts, waste load allocation.	**10**
II	Wastewater Quantity Estimation in urban areas: Generation and collection of wastewater, Estimation of wastewater quantity; Variation in quantity of wastewater; Wastewater Collection Systems: Sanitary, storm and combined sewerage systems, Quantities of sanitary wastes and storm water, Design and analysis of wastewater conveyance system	**10**
III	Urban water quality monitoring: Physical, chemical and biological monitoring of urban water; Guidelines for sample size and location of monitoring stations, Sample analysis	**15**
IV	Water purification in urban areas: Physical, chemical and biological processes, response of streams to biodegradable organic waste; Engineered systems for water and waste water purification	**10**

Recommended Books/References

1. S. C. Chapra, Surface Water Quality Modeling, Waveland Press, 2008.
2. A. David, Chin, Water Quality Engineering in Natural Systems, Wiley Interscience, 2006.
3. D. P. Loucks, J. R. Stedinger and D. A. Haith, Water Resource Systems Planning and Analysis, PH.1981.
4. G. T. Orlob, Mathematical Modelling of Water Quality- Streams, Lakes, and Reservoirs, John Wiley, 1983.
5. R. V. Thomn and J. A. Mueller, Principles of Surface Water Quality Modelling, Harper and Row Publishers, 1987.

Course Outcomes: The students after studying this will able to learn:

- The essential techniques used in urban water management
- The effective measures to supply drinking water to urban people and reduce hazard involved in urban water supply

Course Code	**:**	**WRE626021**
Course Title	**:**	**Climate Change Impact on Water Resources**

Number of Credits	**:**	**3 (L:3,T:0, P:0)**
Course Category	**:**	**Professional Elective Course**

Course Objective: The course emphasizes on the history of earth's climate, climate change, climate change impacts and vulnerability. It also covers the significant influence of anthropogenic and developmental activities on global warming and climate change. Several climate change models are also introduced. The student gains the knowledge of climate change mitigative measures, emission trading and its monitoring.

Course Content:

Unit	Content	Hours
I	Introduction; Global warming aggravations, Earth's climate, climate change, drivers of climate change, Models for climate change, GCMs, RCMs, climate change scenarios; Sector models – water resources, Agricultural, forestry, energy, GHG prediction models, Climate Change Policy Framework: Climate change as a problem, Impacts of climate change, Climate variability and natural resources, United Nations Framework Convention on Climate Change (UNFCCC), Background to the Convention and its aims, Kyoto Protocol and the Flexibility Mechanisms	**15**
II	Climate change impacts; Impacts of climate change on water sector, agriculture sector, infrastructure and energy systems with case studies Vulnerability/adaptation: Need for vulnerability assessment; generic steps, approaches and tools of assessment; adaptation to climate change by various sectors Mitigation: Mitigation measures for climate change, CDM and case studies	**10**
III	Climate change and India; impacts, sectoral and regional vulnerability in India, Evaluation of model simulation over India;	**10**
IV	Emission trading; Evolution of emission trading and design features, trading mechanisms Cost-effective permit markets, the role of transaction costs, the role of technical change, Consequences of emission trading	**10**

Recommended Books/References

1. P. R. Shukla, Climate change and India: vulnerability assessment and adaptation. Universities Press, 2003.
2. K. Soyez and H. Grabl, Basic Facts, Evaluation and Technological Options - Springer Publications, 2008
3. T. H. Tietenberg, Emissions trading: principles and practice an REF Press book, 2006.
4. N. D. Nevers, Air Pollution Control Engineering, McGraw Hill International Editions, Civil Engineering Series, McGraw Hill, 2000.
5. K. Wark, C.F. Warner and W.T. Davis, Air Pollution – Its Origin and Control, Third Edition, Prentice Hall of India Publishers, 1993.

Course Outcomes: On successful completion of the course the students will be able to learn:

- Earth's climate change, identifies the causes for climate change and describes the climate change models and their application.
- Impacts of climate change on various environmental compartments and Stresses the need for vulnerability assessment and its approach.
- Indian scenario of climate change and its impact and reviews various impact predictive models.
- Emission trading, distinguishes different types of emission trading, understands the consequences of emission trading., Highlight the need for emission trading, describe emission trading mechanisms

Course Code	**:**	**WRE621031**
Course Title	**:**	**Water Resources Systems Planning and Management**
Number of Credits	**:**	**3 (L: 2, T: 1, P: 0)**
Course Category	**:**	**Professional Core Course**

Course Objective: Water resource use that is important socially, economically viable, and environmentally sustainable. Additionally, they aim to maximize the advantages and minimize the risks associated with the current hydraulic infrastructure.

Course Content:

Unit	Content	Hours
I	Introduction and Basic Concepts of Water Resources Planning: System Components, Planning and management of water resources systems, systems concept, Advantages and limitations of systems approach, Modeling of Water Resources Systems, Economics in water resources	**5**
II	Introduction to Optimization Techniques in Water Resources: Objective functions, Constraints, Maxima, Minima and saddle points, convex and concave functions, General form of LP, Standard and Canonical forms of LP, Elementary transformations, Graphical method, Feasible and infeasible solutions, Simplex method, Dual and sensitivity analysis,	**10**
III	Dynamic Programming and Applications: Introduction, multistage decision problem, Recursive Equations, Principle of optimality, Discrete DP, Water allocation problem, Capacity expansion problem, Reservoir sizing and Reservoir operation using LP and NLP approaches,	**10**
IV	Constrained and unconstrained optimization in water resources planning, Lagrange multipliers, Kuhn-Tucker conditions	**10**
V	Multi-objective Optimization: Introduction, Non-inferior solutions, Trade-off analysis, Pareto optimal solutions, multipurpose reservoir operation, Weighted and constraint methods, Other methods, Chance constrained LP (CCLP), CCLP for reservoir operation	**10**

Recommended Books/References

1. S.K Jain and V.P Singh, Water Resources Systems Planning and Management, Elsevier Publication, 2003
2. Wurbs and James, Water Resources Engineering, Prentice Hall India Learning Private Limited, 2015
3. J. K. Sharma, Operation Research: Theory and Application, Macmillan Publisher India Ltd, 2012.
4. Rabindran, and Philips, Operation Research, principles and Practises, willy Publisher, 2007
5. S Vedula and P P Mujumdar, Water Resources Systems Modelling Techniques and Analysis," Tata-McGraw Hill, New Delhi, 2005.

Course Outcomes:

- Understanding the Water Resources Systems and Modelling Techniques fundamentals necessary to formulate, solve and analyze engineering problems.
- To develop analytical skills to formulate and solve problems for decision-making under uncertainty
- Students must in a position to formulate and solve optimization models for the design and operation of water resources systems

Course Code	**:**	**WRE 621041**
Course Title	**:**	**Earth and Rock fill Dam**
Number ofCredits	**:**	**3 (L:2, T:1, P:0)**
Course Category	**:**	**Professional Elective Course**

Course Objective: To impart knowledge on suitable construction materials and methods of construction of Earth and Rock fill Dams.

Course Contents:

Units	Contents	Hours
I	Types of earth dams; Design considerations- free board calculations, dam section, upstream slope protection; design considerations in earthquake regions; Filter design; causes of damage and failure, typical case studies.	**8**
II	Seepage control: Control of seepage through earth dam on pervious soil foundation and on impervious base; Cutoff trench; Sheet pile; Alluvial grouting; Slurry trench; Horizontal upstream blanket; Relief wells; Loading berm; Treatment of rock foundations and grouting.	**9**
III	Stability analysis: Total and effective stress methods of analysis; Standard method of slices, Simplified Bishop method; Wedge method, Stability conditions during construction, full reservoir and reservoir draw down.	**8**

IV	Rock fill Dam: Considerations favouring choice of a rock fill dam; Principles of design; Selection of materials; Stability analysis by wedge method, Different types of impervious cores and their locations; Different types of face members; Settlement in rock fill dams; Procedures for placement and compaction of rock fill.	**10**
V	Instrumentations in earth dams: Measurement of deformations, Pore pressures; Quality control; Foundation preparation and treatment; Quality control of materials and control of moisture, laying and compaction; Tests for quality control; Diversion during construction.	**10**

Recommended Books/References

1. L.W. Abramson, T.S. Lee, S. Sharma and G.M. Boyce, Slope Stability and Stabilization Method, John Wiley (Latest Edition).
2. W.P. Creager, J.D. Justin and Hinds, Engineering for Dams, Wiley Estern.
3. R.C. Hirschfeld and S.J. Poulos, Embankment Dam Engineering-Casagrande Volume, John Wiley.
4. B. Singh, and H.D. Sharma, Earth and Rock Fill Dams, Sarita Prakashan (Latest Edition).
5. B. Singh, and R.S. Varshney, Embankment Dam Engineering, Nem Chand and Brothers Latest Edition)

Course Outcome: After study of this course Students will be able to understand methods of construction of earth and rock fill dam and critical reservoir conditions under which dam is liable to be failed.

Course Code	**:**	**WRE621051**
Course Title	**:**	**Application of Soft Computing Techniques**
Number of Credits	**:**	**3 (L: 2, T: 1, P: 0)**
Course Category	**:**	**Core Course**

Course Objective: Introduce students to soft computing concepts and techniques and foster their abilities in designing and implementing soft computing based solutions for real-world and engineering problems. Introduce students to fuzzy systems, fuzzy logic and its applications. Course Content:

Unit	Content	Hours
I	Information and uncertainty, Chance versus ambiguity, Classical sets and fuzzy sets, Logic and reasoning, Fuzzy set operations and fuzzy relations, Membership Functions, Fuzzy Systems,	**10**
II	Decision Making with Fuzzy Information. Fuzzy Classification and Pattern Recognition,	**10**
III	Artificial Neural Networks (ANN), Types of ANN, Learning algorithms, Neuro-Fuzzy Systems,	**15**
IV	Applications in Civil Engineering	**10**

Recommended Books/References

1. S. Haykin, A Comprehensive Foundation Neural Networks, Prentice Hall India, New Delhi, 2008.
2. S. Rajasekaran and G.A. Vijayalakshmi Pai, Nueral Neworks, Fuzzy Logic and Genetic Algorithms – Synthesis and Applications, Prentice-Hall India, New Delhi, 2003.
3. J.R. Jang, Sun Chuen-tsai, and Mizutani Eiji, Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence, PHI Learning, 2009

Course Outcomes: Students will have an understanding of the basic areas of Soft Computing including Artificial Neural Networks, Fuzzy Logic and Genetic Algorithms. Provide the mathematical background for carrying out the optimization associated with neural network learning.

Course Code	**:**	**WRE 626061**
Course Title	**:**	**Isotope Hydrology**
Number of Credits	**:**	**3 (L: 3, T: 0, P: 0)**
Course Category	**:**	**Professional Elective Course**

Course Objective: This course serves as an introductory exploration of isotope tracers in catchment hydrology. It begins by addressing the fundamental aspects of isotope chemistry and subsequently delves into the application of isotope tracing across groundwater hydrology, surface water hydrology, and the identification of plant transpiration sources and ages. The curriculum encompasses both foundational research and practical applications of tracers, catering to a diverse audience including earth scientists, engineers, and ecologists.

Course Content:

Unit	Content	Hours
I	Isotopes, their classifications and characteristics, law of radioactivity and radio isotopes and basic principles of absorption and scattering of alpha and beta particles, gamma rays and neutrons	**10**
II	Principles of detection of radioactive and stable isotopes and related Instruments	**10**
III	Environmental isotopes and their variations in nature. Isotope applications to hydrology; Isotopes as tracers. isotopes as sealed sources for soil moisture variation, recharge to ground water, snow melt equivalent and suspended sediment concentration studies	**10**
IV	Sediment and ground water dating technique for studying sedimentation in water bodies and dynamics of surface and ground water bodies.	**5**
V	Use of isotopes for study of interrelation of hydrologic elements and interconnection of water bodies, Case Studies	**10**

Recommended Books/References

1. Clark, and P. Fritz, Environmental Isotopes in Hydrogeology, Lewis Publishers.

2. E. Mazor, Chemical and Isotopic Groundwater Hydrology, 2nd Edition. Marcel Dekker Inc., 2000.
3. S.M. Rao, Practical Isotope Hydrology, New India Publishing Agency, New Delhi, 2006.
4. IAEA, Stable Isotope Hydrology, Deuterium and Oxygen- 18 in Water Cycle", IAEA, Vienna, Austria, Technical report series no. 210, 1997.
5. S. K. Gupta, Modern Hydrology and Sustainable Water Development, Wiley Blackwell, 2011.

Course Outcomes:
This course aims to equip students with the basic knowledge in application part of isotope in hydrological analysis. Students will also get the knowledge on principles of detection of radioactive and stable isotopes and related instruments.

Course Code	**:**	**WRE 626071**
Course Title	**:**	**Sediment Transportation**
Number of Credits	**:**	**3 (L:2, T:1, P:0)**
Course Category	**:**	**Professional Elective Course**

Course Objective:
To impart knowledge of properties of sediments, methods of sediment transportation estimation and reservoir sedimentation.

Course Content:

Unit	Content	Hours
I	Definition and properties of sediments, categories of sediment, properties of sediment particles i.e., density, fall velocity, drag coefficient, factors affecting fall velocity, bulk properties of sediments.	**8**
II	Sediment transport processes, Incipient motion, Incipient motion critieria, shear stress approach, Shields diagram, velocity approach, Frontier snd Scobey's study, probabilistic consideration, Meyer-Peter and Muller Criterion.	**10**
III	Resistance to flow and bed forms, resistance to flow with rigid boundary, Darcy-Weisbach formula, bed forms, factors affecting bed forms, resistance to flow with movable boundary.	**9**
IV	Bed load transport, shear stress approach, energy slope approach, energy slope approach, discharge approach, etc, suspended load transport, total load transport, Engelund, and Hansen approach, Yang approach.	**10**
V	Reservoir sedimentation, methods of sediment yield determination, methods to control sediment inflow to reservoir, watershed management to control soil erosion.	**8**

Recommended Books/References

1. C. T., Yang, Sediment Transport: Theory and Practice. McGraw-Hill, USA, 1996.

2. P. Y., Julien, Erosion and Sedimentation, Cambridge University Press, 2nd Edition, 2010.
3. R. J., Garde, and K. G. R., Raju, Mechanics of sediment transportation and Alluvial streams Problems, New Age International Ltd. Publishers, 3rd Edition, 2000.

Course Outcomes: Upon successful completion of the course, the students will be able to:

- Gain the knowledge of sediment transportation theories and evolution, and methods to reduce the bed load as well as reservoir sedimentation.
- Gain the fundamental understanding of the forces involved in particle transport in fluids, sediment measurements and controlling sediment loss.
- Learn the best management practices (BMPs) involved in controlling stream erosion and reservoir sedimentation.

Course Code	**:**	**WRE 626081**
Course Title	**:**	**Hydrologic Systems Modelling**
Number of Credits	**:**	**3 (L: 3, T: 0, P: 0)**
Course Category	**:**	**Professional Elective Course**

Course Objective:

The Hydrologic Systems Modeling course is designed to teach a student hydrologic cycle in the nature and how to quantitatively describe those processes using models. The student will learn the fundamentals of hydrology including basic concepts, precipitation, snow and snowmelt, evapotranspiration, subsurface flow, infiltration and soil water movement, and runoff and streamflow. This cause pays equivalent attention to theories and hands-on practices on model application (SWAT) for watershed scale. The students will be taught how to set up and execute weather data driven physical based models, both at a point-scale and a watershed scale, to predict, evapotranspiration, infiltration, soil water distribution, subsurface drainage, runoff, and stream flow in hydrologic systems.

Course Content:

Unit	Content	Hours
I	Introduction, nature of problems in hydrology, physical and systems approach, systems view of hydrologic cycle, hydrologic continuity equation	**5**
II	Linear systems theory, response functions of linear systems, lumped and distributed catchment systems, response function of hydrologic systems for discrete and continuous inputs, derivation of unit hydrograph	**15**
III	Linear conceptual models, linear reservoir and linear channel, Nash, Clarke models, derivation of non-parametric unit hydrograph, derivation of synthetic unit hydrograph Flood routing, hydraulic and hydrologic flood routing, linear, kinematic wave and dynamic wave routing models, parameter estimation of flood routing models	**15**
IV	Hydrologic simulation models (SWAT), modeling of various hydrological processes, overview of standard hydrologic simulation models	**10**

Recommended Books/References

1. V.T. Chow, D.R. Maidment, and L.W. Mays, Applied Hydrology, McGraw Hill Inc. N York, 2010
2. R. H. McCuen., Hydrologic Analysis and Design, Prentice Hall Inc. N York, 2005
3. V.P. Singh, Hydrologic Systems, Prentice Hall Inc., N York, 1986.

Course Outcomes:

- Classify forecasting and prediction problems in hydrology.
- Formulate and solve flood routing models for linear and nonlinear hydrologic systems
- Develop and solve rainfall-runoff models using transformation and simulation
- techniques.
- Develop synthetic unit hydrograph for un-gauged watersheds.

Course Code	**:**	**WRE 626091**
Course Title	**:**	**Hydropower Engineering**
Number of Credits	**:**	**3 (L:2, T:1, P:0)**
Course Category	**:**	**Professional Elective Course**

Course Objective: To introduce the fundamentals of hydropower, transient analysis, and various components of a hydropower plant.

Course Content:

Unit	Content	Hours
I	Introduction: Sources of power -Status of Power potential in the world and India. Transmission voltages and Hydropower -Estimation of water power potential. Source of Hydropower -Runoff and Stream flow. Stream flow analysis - Hydrograph, Mass curve and Flow duration curve.	**5**
II	Hydropower Plants, Classification, Low and High head plants, Pumped storage plants runoff river plants general arrangement of runoff river plants, valley dam plants, high head diversion plants pumped storage plants -advantages -types of pumped storage plants, two and three unit arrangements.	**8**
III	Water Conveyance systems. Penstocks, Anchor blocks -Design criteria for Penstocks -Economical diameter of Penstock. Anchor blocks -Design principles of Anchor blocks, valves, bends and manifolds intakes, canals and tunnels -types of intakes, losses in intakes, air entrainment at intakes, inlet aeration, trash racks.	**10**
IV	Turbines, main types, hydraulic features, turbine site, constructional features -lay out and arrangement. Draft tubes, cavitation in turbines -governing of turbines, turbine characteristics -model testing -water Hammer -resonance in penstocks, surge tanks -types and design principles of simple surge tank.	**12**
V	Power house planning, surface power stations power house structure power house	**10**

	dimensions, lighting and ventilations in power house. Underground power stations location of underground power station components of underground Power station, features of some typical hydro power projects in India.	

Recommended Books/References

1. H.K. Barrows, Water Power Engineering, Tata McGraw Hill Publishing Company Ltd., 1943.
2. M.H. Choudhary, Applied Hydraulic Transients, Springer New York, 2013.
3. M.M. Dandekar and K.N. Sharma, Water Power Engineering, Vikas Publishing House Pvt. Ltd., 2013.
4. M. M. Deshmukh Water Power Engineering, Dhanpat Rai & Sons, 1978.
5. P.S. Nigam, Hydro Electric Engineering, Nem Chand & Bros., 2001.
6. R.S. Varshney, Hydro Power Structures, Nem Chand & Bros., 2001.

Course Outcomes: Upon successful completion of this course, the students will be able to:

- Able to prepare a load curve and calculate firm power and secondary power from power duration curve.
- Understand types and principal components of hydropower plants, types and working of turbines, water hammer, and surges and their effect on the operation of hydropower units, determine the economical diameter of penstocks and, estimate energy generation.
- Understand the layout and components of the underground powerhouse and surface powerhouse.

Course Code	**:**	**WRE 626101**
Course Title	**:**	**Watershed Management**
Number of Credits	**:**	**3 (L: 2, T: 1, P: 0)**
Course Category	**:**	**Professional Elective Course**

Course Objective: The course offers practical expertise in analyzing soil and water resource degradation and executing strategies for their conservation. It delivers a comprehensive exploration of engineering practices in watershed management to maximize the advantages derived from effective watershed management techniques.

Course Content:

Unit	Content	Hours
I	Basics: Watershed concept, Identification and characterization of watersheds, Hydrological and geomorphological characteristics of watersheds, Analysis of watershed, Coding of watershed, Land capability classification and soil maps.	**5**
II	Watershed Planning: Planning principles – collection of data – present land use - Preparation of watershed development plan - Estimation of costs and benefits - Financial plan – selection of implementation agency - Monitoring and evaluation system	**10**

III	Watershed erosion processes and its prevention, Instrumentation and measurement of watershed management indicators, Mechanical and vegetative interventions for prevention of erosion and moisture conservation in watersheds; Water quality issues in watersheds, Optimal land use planning in watersheds, Management of saline and alkaline soils	**10**
IV	Water Conservation Practices: In-situ & Ex-situ moisture conservation principle and practices - Afforestation principle - Micro catchment water harvesting - Ground water recharge – percolation ponds -Water harvesting - Farm pond - Supplemental irrigation - Evaporation suppression - Seepage reduction.	**10**
V	Watershed Development Programme: River Valley Project (RVP) - Hill Area Development Programme (HADP) - National Watershed Development Programme for Rainfed Agriculture (NWDPRA) - Other similar projects operated in India – Govt. of India guidelines on watershed development programme - Watershed based rural development – infrastructure development - Use of Aerial photography and Remote sensing in watershed management - Role of NGOs in watershed development.	**10**

Recommended Books/References

1. R. Suresh, Soil and Water Conservation Engineering, Standard Publishers & Distributors, New Delhi, 2005.
2. Ghanashyam Das, Hydrology and Soil Conservation Engineering", Prentice Hall of India Private Limited, New Delhi, 2000.
3. Gurmel Singh, Manual of soil and water conservation practices, Oxford & IBH publishing Co. New Delhi, 2004.
4. R. Suresh, Land and water management principles, Standard Publishers & Distributors, New Delhi, 2008.
5. R.P Tripathi and H. P. Singh, Soil Erosion and Conservation, Willey Eastern Ltd., New Delhi, 2002.
6. V.V.N. Murthy, Land and Water Management, Kalyani Publishing, New Delhi, 2005.
7. E. M. Tideman, Watershed Management, Omega Scientific Publ. 1996.
8. Ghanshyam Das, Hydrology and Soil Conservation Engineering, PHI Learning Private Limited, 2009.
9. W.A. Hall and J.A. Dracup, Water Resources Systems Engineering, Mc Graw Hill, 1970.
10. R.W. Hexem and E.O. Heady, Water Production Functions for Irrigated Agriculture, Iowa State University Press, 1978.
11. L.D. James and R. L. Robert, Economics of Water Resources Planning,

Course Outcomes: After completion of the course,

- The students will have a thorough knowledge on watershed planning, development and management strategies through different soil and water conservation approaches.
- Suggest technical measures for soil erosion control both due to water and wind
- Assess the current status of the watershed at field, by taking up accurate investigation measures and conduct survey

Course Code	**:**	**WRE 626111**
Course Title	**:**	**River Engineering**
Number of Credits	**:**	**3 (L:2, T:1, P:0)**
Course Category	**:**	**Professional Elective Course**

Course Objective: To understand theoretical concepts of water and sediment movements in rivers and also to inculcate the benefits of fluvial system to the society.

Course Content:

Unit	Content	Hours
I	Introduction: Primary function of a river, River uses and measures, Water and Sediment load of rivers, Rivers in India, Himalaya and Peninsular.	**5**
II	River morphology, Plan form variations and river channel pattern, River dynamics: degradation and aggradation of river bed, and River gauging.	**8**
III	River Equilibrium: Stability of Channel, regime relations, river bend equilibrium, hydraulic geometry of downstream, Bars and meandering, Characteristics of braided and meandering rivers, Confluences and branches, River Data base.	**10**
IV	Sediment transport in rivers, Bed load and suspended load transport for uniform and non-uniform bed material, Total load equations, sediment sampling.	**12**
V	Reservoir planning, Reservoir sedimentation, River training works, Principles of stabilisation and rectification of rivers, River bank stability analysis, Design of river training works like groynes, guide banks, gabions, Hydraulic modelling of rivers.	**10**

Recommended Books/References

1. R. J. Garde, River Morphology, New Age International Publishers, 2006.
2. R. J. Garde and K. G. Ranga Raju, Mechanics of Sediment Transportation and Alluvial Stream Problems, New Age International Publishers, 2000.
3. P. P. H. Jansen, Principals of River Engineering, VSSD Publications, 1994.
4. Pierre Y. Julien, River Mechanics, Cambridge University Press, 2002.
5. K. L. Rao, India's Water Wealth, Orient Longman Ltd., 1979.

Course Outcomes: Upon successful completion of the course, the students will be able to learn the complex behavior of rivers and gain the skills to take up research activities in river engineering.

Course Code	**:**	**WRE626121**
Course Title	**:**	**Advance Irrigation and Drainage Engineering Lab**
Number of Credits	**:**	**1 (L: 0, T: 0, P: 2)**

Course Category	:	Lab Course

Course Objective: to determine the soil properties, infiltration rate, soil moisture, wilting point and irrigation water measurement.

Course Content:

Experiment No	Title
1	Measurement of soil moisture: moisture content, density, mass wetness, volume wetness
2	Measurement of infiltration characteristics by using double ring infiltrometer: Basic infiltration rate, accumulated infiltration rate, infiltration velocity, infiltration rate
3	Measurement of soil moisture tension: soil moisture, matric potential, pressure potential, gravitational potential
4	Determination of bulk density, field capacity and wilting point
5	Measurement of irrigation water using weir, flume and orifice

Recommended Books/References

1. Das and Saikia, Irrigation and Hydropower Engineering, PHI Learning Pvt Ltd.
2. K.N Sharma, Water Power Engineering, Vikas Publishing House
3. A. Michael, Irrigation Theory and Practice-2Nd Edn, Vikas publishing house, 2009.
4. S. K. Garg, Irrigation Engineering and Hydraulic Structures: Water Resources Engineering (Vol. II). Khanna Publisher, 2020.
5. V.V.N. Murty, and T. Kei, Land and water development for agriculture in the Asia-Pacific region. Science Publishers, Inc., 1996.

Course Outcomes: at the successful completion the course, the students will learn:

- To determine the basic properties of soil.
- To determine the infiltration rate
- Concept of water constants, soil water potentials etc.

Course Code	**:**	**WRE624131**
Course Title	**:**	**Mini Project**
Number of Credits	**:**	**2 (L:0, T:0, P:4)**
Course Category	**:**	**Professional Core Course**

Course Objective: To impart the knowledge of the basics of thesis preparation, journal article writing and delivering effective presentation

Course Content:

- Mini Project will have mid semester presentation and end semester presentation.
- Mid semester presentation will include identification of the problem based on the literature review on the topic referring to latest literature available.
- End semester presentation should be done along with the report on identification of topic for the work and the methodology adopted involving scientific research, collection and analysis of data, determining solutions highlighting individuals' contribution.
- Continuous assessment of Mini Project at Mid Sem and End Sem will be monitored by the departmental committee.

Course Outcomes: Upon successful completion of the course, the students will be able to:

- Write the thesis/report as per the standard guidelines.
- Understand the important points to consider before the commencement of the problem identification for the research work.
- Differentiate between the journal articles, conference papers and other technical reports.
- Deliver effective presentation on the topic of concern.