**DEPARTMENT OF CIVIL ENGINEERING**

**ANNA UNIVERSITY, CHENNAI**

## OUR VISION

Department of Civil Engineering, Anna University, shall strive hard to develop and impart technical knowledge and professional skills required for Civil Engineering practice through excellence in teaching, research and consultancy to address sustainable infrastructure development needs at local, national and International levels.

## OUR MISSION

Department of Civil Engineering, Anna University shall contribute to technological and social development by

1. Providing a firm scientific and technological base in Civil Engineering to achieve self reliance.
2. Providing quality education through innovation in teaching practices at par with global standards.
3. Nurturing leadership and entrepreneurship qualities with ethical values.
4. Developing and disseminating latest knowledge and technologies in emerging areas of Civil Engineering.
5. Sharing intellectual resources and infrastructure facilities through collaborative partnership.
6. Ensuring supporting conditions for enhancing the employability skills.

**ANNA UNIVERSITY, CHENNAI**

**UNIVERSITY DEPARTMENTS**

**REGULATIONS 2023**

**CHOICE BASED CREDIT SYSTEM**

# M.E. HYDROLOGY AND WATER RESOURCES ENGINEERING (FULL-TIME)

## PROGRAMME EDUCATIONAL OBJECTIVES(PEOs):

Graduates of the Programme M E Hydrology and Water Resources Engineering will

**PEO1** Gain knowledge and skills in Water Resources engineering which will enable them to have a career and professional accomplishment in the public or private sector organizations

**PEO2** Become consultants in Water Resources Engineering and solve complex real life issues related to analysis, design and maintenance of structures under various environmental conditions

**PEO3** Contribute to the enhancement of knowledge in Water Resources Engineering by performing quality research in institutions of international repute or in Research organizations or Academia.

**PEO4** Practice their profession with good communication, leadership, ethics and social responsibility and formulate solutions that are technically sound, economically feasible, and socially acceptable.

**PEO5** Graduates will function in multi-disciplinary teams and adapt to evolving technologies through life-long learning and innovation

## PROGRAMME OUTCOMES(POs):

After going through the four years of study, our Water Resources Engineering Graduates will exhibit ability to:

| PO | Attributes | Programme Outcomes |
|---|---|---|
| **1** | Research Aptitude | An ability to independently carry out research/investigation and development work to solve practical problems |
| **2** | Technical Documentations | An ability to write and present a substantial technical report/document |
| **3** | Technical Competence | Students should be able to demonstrate a degree of mastery over the area as per the specialization of the programme. The mastery should be at a level higher than the requirements in the appropriate bachelor programme. |
| **4** | Handle Complex Problems | Use research based knowledge, resources, methods, appropriate techniques and tools to solve water resources engineering complex issues with an understanding of limitations. |
| **5** | Environmental Sustainability and Societal Ethics | Ensure development of socially relevant and eco-friendly hydrological, hydraulics and environmental projects by applying technical knowledge, ethical principles and sustainable engineering practices |
| **6** | Life-long Learning | Recognize the need for independent, life-long learning and adapt to emerging technologies in water resources and solutions to novel problems. |

**PEO/PO Mapping:**

| PROGRAMME EDUCATIONAL OBJECTIVES | PROGRAMME OUTCOMES | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| **I.** | 3 | 2 | 2 | 2 | 2 | 2 |
| **II.** | 3 | 1 | 2 | 2 | 2 | 3 |
| **III.** | 3 | 2 | 2 | 2 | 2 | 2 |
| **IV.** | 3 | 3 | 2 | 3 | 2 | 2 |
| **V.** | 3 | 3 | 2 | 3 | 2 | 3 |

• 1-low, 2-medium, 3-high

**MAPPING OF COURSE OUTCOME AND PROGRAMME OUTCOME**

| | | COURSE NAME | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|---|---|
| YEAR I | SEMESTER I | Probability and Statistical Methods | 3 | 3 | 3 | 3 | 2 | 2 |
| | | Research Methodology and IPR | | | | | | |
| | | Surface Water Hydrology | 2 | 2 | 2 | 2 | 3 | 3 |
| | | Groundwater Hydrology | 3 | 2 | 3 | 3 | 3 | 3 |
| | | Advanced Fluid Mechanics | 3 | 2 | 3 | 3 | 3 | 3 |
| | | Surface Water Quality Modelling | 2 | 3 | 2 | 3 | 3 | 3 |
| | SEMESTER II | Advanced Hydrologic Analysis and Design | 2 | 2 | 3 | 3 | 3 | 3 |
| | | Groundwater Modelling and Management | 3 | 2 | 3 | 3 | 3 | 3 |
| | | Open Channel Hydraulics | 3 | 2 | 3 | 3 | 2 | 3 |
| | | Systems Analysis in Water Resources | 3 | 1 | 3 | 3 | 2 | 2 |
| | | Remote Sensing and GIS for Water Resources | 2 | 2 | 2 | 3 | 3 | 3 |
| | | Professional Elective I | | | | | | |
| YEAR II | SEMESTER III | Professional Elective II | | | | | | |
| | | Professional Elective III | | | | | | |
| | | Professional Elective IV | | | | | | |
| | | Practical Training** | 3 | 3 | 3 | 3 | 3 | 3 |
| | | Project Work I | 3 | 3 | 3 | 2 | 3 | 2 |
| | SEMESTER IV | Project Work II | 3 | 3 | 3 | 2 | 3 | 2 |

• 1-low, 2-medium, 3-high

**MAPPING FOR PROFESSIONAL ELECTIVE COURSES [PEC]**

| S. NO. | COURSE TITLE | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|---|
| 1. | Flood Modelling and Drought Management | 2 | 2 | 3 | 3 | 3 | 3 |
| 2. | Watershed Conservation and Management | 3 | 2 | 3 | 3 | 3 | 3 |
| 3. | Climate Change and Water Resources | 2 | 2 | 3 | 3 | 3 | 3 |
| 4. | Environmental Impact Assessment for Water Resources | 2 | 2 | 2 | 3 | 3 | 3 |
| 5. | Urban Water Resources Management | 2 | 1 | 2 | 2 | 2 | 2 |
| 6. | Waterpower and Dam Engineering | 3 | 2 | 3 | 3 | 3 | 3 |
| 7. | Water Supply and Buried Pipelines | 3 | 1 | 3 | 3 | 3 | 3 |
| 8. | Computational Intelligence for Hydro Systems | 3 | 1 | 3 | 3 | 3 | 3 |
| 9. | Legal Aspects of Water Resources | 2 | 1 | 2 | 3 | 3 | 3 |
| 10. | Circular Water Economy | 2 | 3 | 2 | 3 | 3 | 3 |
| 11. | Integrated River Basin Management | 1 | 2 | 2 | 3 | 3 | 3 |
| 12. | Dam Hydraulics and Safety Engineering | 3 | 1 | 3 | 2 | 3 | 3 |
| 13. | Radar Meteorology | 2 | 2 | 3 | 3 | 3 | 3 |
| 14. | Wastewater Treatment and Utilization | 3 | 2 | 3 | 3 | 3 | 3 |
| 15. | Water, Sanitation and Health | 1 | 2 | 2 | 2 | 3 | 3 |
| 16. | Drought Risk Assessment and Management | 2 | 2 | 2 | 3 | 2 | 3 |

• 1-low, 2-medium, 3-high

**ANNA UNIVERSITY, CHENNAI**
**UNIVERSITY DEPARTMENTS**
**M.E. HYDROLOGY AND WATER RESOURCES ENGINEERING (FULL-TIME)**
**REGULATIONS – 2023**
**CHOICE BASED CREDIT SYSTEM**
**CURRICULA AND SYLLABI FOR I TO IV SEMESTERS**

## SEMESTER I

| S. NO. | COURSE CODE | COURSE TITLE | CATEGORY | PERIODS PER WEEK | | | TOTAL CONTACT PERIODS | CREDITS |
|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | | |
| **THEORY** | | | | | | | | |
| 1. | MA3160 | Probability and Statistical Methods | FC | 4 | 0 | 0 | 4 | 4 |
| 2. | HW3101 | Surface Water Hydrology | PCC | 3 | 0 | 0 | 3 | 3 |
| 3. | HW3102 | Groundwater Hydrology | PCC | 3 | 0 | 0 | 3 | 3 |
| 4. | HW3103 | Advanced Fluid Mechanics | PCC | 3 | 0 | 0 | 3 | 3 |
| 5. | HW3104 | Surface Water Quality Modelling | PCC | 3 | 0 | 4 | 7 | 5 |
| 6. | RM3151 | Research Methodology and IPR | RMC | 2 | 1 | 0 | 3 | 3 |
| | | | **TOTAL** | **18** | **1** | **4** | **23** | **21** |

## SEMESTER II

| S. NO. | COURSE CODE | COURSE TITLE | CATEGORY | PERIODS PER WEEK | | | TOTAL CONTACT PERIODS | CREDITS |
|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | | |
| **THEORY** | | | | | | | | |
| 1. | HW3201 | Advanced Hydrologic Analysis and Design | PCC | 3 | 0 | 0 | 3 | 3 |
| 2. | HW3202 | Groundwater Modelling and Management | PCC | 3 | 0 | 0 | 3 | 3 |
| 3. | HW3203 | Open Channel Hydraulics | PCC | 3 | 0 | 0 | 3 | 3 |
| 4. | HW3204 | Systems Analysis in Water Resources | PCC | 3 | 0 | 4 | 7 | 5 |
| 5. | HW3251 | Remote Sensing and GIS for Water Resources | PCC | 3 | 0 | 4 | 7 | 5 |
| 6. | | Professional Elective I | PEC | 3 | 0 | 0 | 3 | 3 |
| | | | **TOTAL** | **18** | **0** | **8** | **26** | **22** |

## SEMESTER III

| S. NO. | COURSE CODE | COURSE TITLE | CATE GORY | PERIODS PER WEEK | | | TOTAL CONTACT PERIODS | CREDITS |
|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | | |
| **THEORY** | | | | | | | | |
| 1. | | Professional Elective II | PEC | 3 | 0 | 0 | 3 | 3 |
| 2. | | Professional Elective III | PEC | 3 | 0 | 0 | 3 | 3 |
| 3. | | Professional Elective IV | PEC | 3 | 0 | 0 | 3 | 3 |
| **PRACTICALS** | | | | | | | | |
| 4. | HW3311 | Practical Training (4 Weeks) | EEC | 0 | 0 | 0 | 0 | 2 |
| 5. | HW3312 | Project Work I | EEC | 0 | 0 | 12 | 12 | 6 |
| | | | **TOTAL** | **9** | **0** | **12** | **21** | **17** |

## SEMESTER IV

| S. NO. | COURSE CODE | COURSE TITLE | CATE GORY | PERIODS PER WEEK | | | TOTAL CONTACT PERIODS | CREDITS |
|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | | |
| **PRACTICALS** | | | | | | | | |
| 1. | HW3411 | Project Work II | EEC | 0 | 0 | 24 | 24 | 12 |
| | | | **TOTAL** | **0** | **0** | **24** | **24** | **12** |

**TOTAL CREDITS TO BE EARNED FOR AWARD OF THE DEGREE:: 72**

## FOUNDATION COURSES (FC)

| S. NO. | COURSE CODE. | COURSE TITLE | PERIODS PER WEEK | | | CREDITS |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1. | MA3160 | Probability and Statistical Methods | 4 | 0 | 0 | 4 |

## PROFESSIONAL CORE COURSES (PCC)

| SL NO. | COURSE CODE. | COURSE TITLE | PERIODS PER WEEK | | | CREDITS |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1. | HW3101 | Surface Water Hydrology | 3 | 0 | 0 | 3 |
| 2. | HW3102 | Groundwater Hydrology | 3 | 0 | 0 | 3 |
| 3. | HW3103 | Advanced Fluid Mechanics | 3 | 0 | 0 | 3 |
| 4. | HW3104 | Surface Water Quality Modelling | 3 | 0 | 4 | 5 |
| 5. | HW3201 | Advanced Hydrologic Analysis and Design | 3 | 0 | 0 | 3 |
| 6. | HW3202 | Groundwater Modelling and Management | 3 | 0 | 0 | 3 |
| 7. | HW3203 | Open Channel Hydraulics | 3 | 0 | 0 | 3 |
| 8. | HW3204 | Systems Analysis in Water Resources | 3 | 0 | 4 | 5 |
| 9. | HW3251 | Remote Sensing and GIS for Water Resources | 3 | 0 | 4 | 5 |
| | | | | | **Total Credits** | **27** |

## EMPLOYABILITY ENHANCEMENT COURSES (EEC)

| S. No. | COURSE CODE | COURSE TITLE | PERIODS PER WEEK | | | CREDITS |
|---|---|---|---|---|---|---|
| | | | Lecturer | Tutorial | Practical | |
| 1. | HW3311 | Practical Training (4 Weeks) | 0 | 0 | 0 | 2 |
| 2. | HW3312 | Project Work I | 0 | 0 | 12 | 6 |
| 3. | HW3411 | Project Work II | 0 | 0 | 24 | 12 |
| | | | | | **Total Credits** | **21** |

## PROFESSIONAL ELECTIVE COURSES

| S. NO. | COURSE CODE | COURSE TITLE | PERIODS PER WEEK | | | TOTAL CONTACT PERIODS | CREDITS |
|---|---|---|---|---|---|---|---|
| | | | L | T | P | | |
| 1. | HW3001 | Flood Modelling and Drought Management | 3 | 0 | 0 | 3 | 3 |
| 2. | IW3051 | Watershed Conservation and Management | 3 | 0 | 0 | 3 | 3 |
| 3. | IW3052 | Climate Change and Water Resources | 3 | 0 | 0 | 3 | 3 |
| 4. | HW3051 | Environmental Impact Assessment for Water Resources | 3 | 0 | 0 | 3 | 3 |
| 5. | HW3002 | Urban Water Resources Management | 3 | 0 | 0 | 3 | 3 |
| 6. | HW3003 | Waterpower and Dam Engineering | 3 | 0 | 0 | 3 | 3 |
| 7. | HW3004 | Water Supply and Buried Pipelines | 3 | 0 | 0 | 3 | 3 |
| 8. | HW3005 | Computational Intelligence for Hydro Systems | 3 | 0 | 0 | 3 | 3 |
| 9. | HW3052 | Legal Aspects of Water Resources | 3 | 0 | 0 | 3 | 3 |
| 10. | IW3053 | Circular Water Economy | 3 | 0 | 0 | 3 | 3 |
| 11. | HW3006 | Integrated River Basin Management | 3 | 0 | 0 | 3 | 3 |
| 12. | HW3007 | Dam Hydraulics and Safety Engineering | 3 | 0 | 0 | 3 | 3 |
| 13. | HW3053 | Radar Meteorology | 3 | 0 | 0 | 3 | 3 |
| 14. | IW3054 | Wastewater Treatment and Utilization | 3 | 0 | 0 | 3 | 3 |
| 15. | IW3055 | Water, Sanitation and Health | 3 | 0 | 0 | 3 | 3 |
| 16. | IW3056 | Drought Risk Assessment and Management | 3 | 0 | 0 | 3 | 3 |

## RESEARCH METHODOLOGY AND IPR COURSES (RMC)

| S NO. | COURSE CODE | COURSE TITLE | PERIODS PER WEEK | | | CREDITS |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1. | RM3151 | Research Methodology and IPR | 2 | 1 | 0 | 3 |
| | | | | | **TOTAL CREDITS:** | **3** |

## SUMMARY

| | NAME OF THE PROGRAMME: M.E. HYDROLOGY AND WATER RESOURCES ENGINEERING | | | | | |
|---|---|---|---|---|---|---|
| **S. No.** | **SUBJECT AREA** | **CREDITS PER SEMESTER** | | | | **CREDITS TOTAL** |
| | | **I** | **II** | **III** | **IV** | |
| 1. | FC | **4** | **0** | **0** | **0** | **4** |
| 2. | PCC | **14** | **19** | **0** | **0** | **33** |
| 3. | PEC | **0** | **3** | **9** | **0** | **12** |
| 4. | EEC | **0** | **0** | **08** | **12** | **20** |
| 5. | RMC | **3** | **0** | **0** | **0** | 3 |
| | **Total** | **21** | **22** | **17** | **12** | **72** |

**MA3160 PROBABILITY AND STATISTICAL METHODS L T P C**
**4 0 0 4**

**UNIT I ONE DIMENSIONAL RANDOM VARIABLES 12**

Random variables - Probability function – Moments – Moment generating functions and their properties – Binomial, Poisson, Geometric, Uniform, Exponential, Gamma and Normal distributions – Functions of a Random Variable.

**UNIT II TWO DIMENSIONAL RANDOM VARIABLES 12**

Joint distributions – Marginal and Conditional distributions – Functions of two dimensional random variables – Regression Curve – Correlation.

**UNIT III ESTIMATION THEORY 12**

Unbiased Estimators – Method of Moments – Maximum Likelihood Estimation - Curve fitting by Principle of least squares – Regression Lines.

**UNIT IV TESTING OF HYPOTHESES 12**

Sampling distributions - Type I and Type II errors - Tests based on Normal, t, Chi-Square and F distributions for testing of mean, variance and proportions – Tests for Independence of attributes and Goodness of fit.

**UNIT V MULTIVARIATE ANALYSIS 12**

Random Vectors and Matrices - Mean vectors and Covariance matrices - Multivariate Normal density and its properties - Principal components: Population principal components – Principal components from standardized variables.

**TOTAL: 60 PERIODS**

**OUTCOMES:**

**At the end of the course, students will be able to**

**CO1** Use the appropriate and relevant, fundamental and applied mathematical and statistics knowledge and methodologies in solving practical problem.

**CO2** Bring together and flexibly apply knowledge to characterize, analyse and solve a wide range of problems.

**CO3** Understand the balance between the complexity/accuracy of the mathematical/statistical models used and the timeliness of the delivery of the solution.

**CO4** Steeped in research methods and rigor.

**CO5** Develop critical thinking based on empirical evidence and the scientific approach to development.

**REFERENCES:**


1. Dallas E Johnson , “Applied multivariate methods for data analysis”, Thomson and Duxbury press, Singapore, 1998.
2. Gupta S.C. and Kapoor V.K. “Fundamentals of Mathematical Statistics”, Sultan and Sons, 11th Edition, Reprint, New Delhi, 2019.
3. Jay L. Devore, “Probability and statistics for Engineering and Sciences”, Thomson and Duxbury, 9th Edition, Singapore, Boston, 2016.
4. Krishnaiah K. and Shahabudeen P, “Applied Design of Experiments and Taguchi Methods”, PHI, New Delhi, 2012.
5. Richard A. Johnson and Dean W. Wichern, “Applied Multivariate Statistical Analysis”, Pearson Education, Fifth Edition, 6th Edition, New Delhi, 2013.
6. Richard Johnson. ”Miller & Freund‟s Probability and Statistics for Engineer”, Prentice Hall of India Private Ltd., 8th Edition, New Delhi, 2011.

**CO-PO MAPPING**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 3 | 3 | 2 | 2 |
| **CO2** | 3 | 3 | 3 | 3 | 2 | 2 |
| **CO3** | 3 | 3 | 3 | 3 | 2 | 2 |
| **CO4** | 3 | 3 | 3 | 3 | 2 | 2 |
| **CO5** | 3 | 3 | 3 | 3 | 2 | 2 |
| **Avg** | **3** | **3** | **3** | **3** | **2** | **2** |

• 1-low, 2-medium, 3-high

**HW3101 SURFACE WATER HYDROLOGY L T P C**
**3 0 0 3**

**UNIT I HYDROMETEOROLOGY 9**

Hydrologic cycle and its components – Hydrological System Concept - Global water budget – Practical applications – Hydrometeorology – Constituents of atmosphere – Vertical structure of the atmosphere – Climate and Weather – Meteorological Observations - Formation of precipitation – Types and forms of precipitation - Indian Monsoon and climate.

**UNIT II RAINFALL 9**

Measurement of rainfall – Rain gauges – Radar Measurement of rainfall - Rainfall Hyetograph – Intensity Duration and Frequency analysis – Consistency – Missing data – Rain gauge network – Average depth of rainfall analysis – Spatial analysis using GIS – Annual rainfall of India and Tamil Nadu - Prabable Maximum Precipitation - Rainfall extremes in India and Tamil Nadu.

**UNIT III ABSTRACTIONS 9**

Water losses - Initial losses and Infiltration Process – Interception and depression storage – Detention and retention - Evaporation – Evaporimeters – Estimation of Evaporation - Evapotranspiration – Field Measurement – Empirical Equations - Infiltration – Infiltrometers – Infiltration Equations - Modeling of Infiltration Capacity - Infiltration Indices.

**UNIT IV CATCHMENT RUNOFF AND YIELD 9**

Concept of catchment – Linear, Areal and Relief Aspects – Detailed study of Runoff process – Factors affecting Runoff – Estimation of Runoff Volume: Empirical Models, Conceptual Models - Flow Characteristic Curves and Estimation of Reservoir Storage - Hydrograph – Unit Hydrograph – Base Flow Separation - DRH – ERH - Synthetic Hydrograph – Instantaneous Unit Hydrograph - Runoff estimation - Strange and SCS methods – SWAT and HEC-HMS model.

**UNIT V STREAMFLOW MEASUREMENT 9**

Stage and Velocity Measurement – Gauges – Current meter - Discharge measurement – Area Velocity method - Area Slope method – Discharge Measuring Structures - Indirect Streamflow Measurement - Stage Discharge Relationship and Rating Curve - Dilution Technique – Water Conservation – Rain water and Runoff Harvesting in Rural and Urban Areas – Concept of environmental flow.

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES:**

- On completion of the course, the student is expected to

**CO1** Describe the hydrologic cycle and devices for hydro meteorological Measurements
**CO2** Explain different rain gauges and Perform various kind of Rainfall Analysis
**CO3** Estimate various losses such as evaporation, Evapotranpiration and Infiltration.
**CO4** Discuss the various methods of runoff estimation and derive hydrographs
**CO5** Demonstrate the various methods of Stream flow measurement and water harvesting Techniques.

**REFERENCES:**


1. Ven Te Chow, D.R. Maidment and Lorry W. Mays, Applied Hydrology, McGraw Hill education, First edition, 2017.
2. K. Subramanya, Engineering Hydrology, McGraw Hill Education (India) Private Limited – Fourth edition, 2013
3. K.C Patra, Hydrology and Water Resources Engineering, Narosa Publications, 2008, Second Edition, New Delhi.
4. P. Jeya Rami Reddy, Hydrology, Laxmi Publications, New Delhi, Third edition 2016


**CO-PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 1 | 2 | 2 |
| **CO2** | 3 | 1 | 2 | 2 | 2 | 2 |
| **CO3** | 2 | 2 | 2 | 2 | 3 | 3 |
| **CO4** | 2 | 2 | 3 | 3 | 3 | 3 |
| **CO5** | 2 | 2 | 3 | 3 | 3 | 3 |
| **Avg** | **2** | **2** | **2** | **2** | **3** | **3** |

• 1-low, 2-medium, 3-high

**HW3102 GROUNDWATER HYDROLOGY L T P C**
**3 0 0 3**

**UNIT I GROUNDWATER HYDRAULICS 8**

Introduction to Groundwater – Hydro meteorology – Groundwater in Hydrologic Cycle –– Hydrogeology: Groundwater in consolidated and unconsolidated formation –– Types of aquifers - Water bearing materials – Aquifer parameters and its determination – Steady state groundwater flow - Movement of Groundwater - Darcy"s law and its limitations - Stream lines and flow net analysis – Principles of Groundwater Flow and its equation - Flow Potential theory – Dupuit Forchheimer Assumptions - Discharge and draw down for various condition of groundwater flow.

**UNIT II WELL HYDRAULICS 10**

Pumping Test Analysis: Steady State Flow into a Well – Thiem's Assumptions – Radial flow into a well – Theis and Jacob's Equation - Determining aquifer parameters for unconfined, leaky and non-leaky aquifers – steady State and transient conditions – Law of Conditions - Slug test – Locating hydro geological boundaries – Image well theory – Barrier and Recharge Boundary – Method of Images – Multiple Well Systems – Partial penetration of well system – Interference of wells – Well losses –Specific capacity of wells – Safe yield –Hydraulics of large diameter wells.

**UNIT III WELL DESIGN AND CONSTRUCTION 8**

Well design criteria:– Filter design – Artificial and natural packing –- Well drilling methods: Well Revitalisation - Blasting techniques – Well Construction - Recovering well screens – Fishing operation well Development - Well Completion – Well Disinfection –Horizontal wells: Collector wellsand Infiltration galleries – Yield test and selection of pump sets.

**UNIT IV GROUNDWATER PROSPECTING 10**

Geophysical Investigations: Surface Geophysical Techniques – Electrical Resistivity Method – Seismic refraction method – Borehole Geophysical Techniques – Electric logging – Radioactive logging and other logging methods – Downhole photo graphy – Dowsing.

**UNIT V SPECIAL TOPICS 9**

Methods of Groundwater Recharge – Groundwater Basin Management-Groundwater Assessment and Balance Equation – GEC Norms – Seawater intrusion in coastal aquifers – Land Subsidence – Groundwater flow in Hard Rock System: conceptual models – structure and hydrodynamic properties of hard rock aquifers.

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES:**

On completion of the course, the student is expected to be able to

**CO1** Apply the knowledge of groundwater basics to study the groundwater movementand its potential for confined and unconfined aquifers.

**CO2** Understanding the steady, unsteady flow conditions, Image well concepts for the groundwater flow measurements

**CO3** Adopt design concept for various wells in different hydrogeological formations and toconstruct the wells for different purposes

**CO4** Applying the various geophysical investigation techniques to understand about the groundwater availability

**CO5** Apply the creative and advance techniques in groundwater model development for management of groundwater resources.

**REFERENCES:**


1. H.M Raghunath , "*Ground Water Hydrology*", New Age International (P) Limited, New Delhi, 2015
2. D.K. Todd, Larry W. Mays *Groundwater Hydrology*, John Wiley & Sons, Inc, New York, 2004.
3. J. Bear, *Hydraulics of Groundwater*, McGraw-Hill, New York, 1979.
4. H. Bouwer, *Groundwater Hydrology*, McGraw-Hill, New York, 2013.
5. Driscoll, *Groundwater and Wells*, Johnson Filtration Systems, Inc., 1986.
6. C.S.P Ojha, R. Berndtsson, and P . Bhunya, *Engineering Hydrology*, Oxford University Press,New Delhi, 2008.
7. A.K. Rastogi, *Numerical Groundwater Hydrology*, 2011


**CO-PO MAPPING**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | 2 | 2 | 2 |
| **CO2** | 3 | 2 | 3 | 3 | 3 | 2 |
| **CO3** | 3 | 2 | 3 | 3 | 3 | 3 |
| **CO4** | 3 | 2 | 3 | 3 | 3 | 3 |
| **CO5** | 3 | 2 | 3 | 3 | 3 | 3 |
| **Avg** | **3** | **2** | **3** | **3** | **3** | **3** |

• 1-low, 2-medium, 3-high

**HW3103 ADVANCED FLUID MECHANICS L T P C**

**3 0 0 3**

**UNIT I FLUID STATICS AND KINEMATICS 9**

Fundamental concepts of fluid flow and fluid properties – Pressure and floatation - ,–scalars and vectors for fluid flow velocities and forces - Control volume concepts – Fluid flow analysis by,. Lagrangian and Eulerian description. Ideal fluid flow – Stream function and velocity potential function – Flow net analysis.

**UNIT II CONSERVATION LAWS AND FLUID DYNAMICS 9**

Reynolds transport theorem - conservation of mass, momentum and energy - Navier-Stokes equation– Euler's and Bernoulli's equation – Application of Bernoulli's equation for flow measuring devices.

**UNIT III LAMINAR FLOW AND FLOW THROUGH PIPES 9**

Laminar flow – Turbulent flow – Definitions - laminar flow between fixed and moving parallel plates, Hele-Shaw flow – Laminar flow through pipes – Hagen-poiseuille's equation.

**UNIT IV BOUNDARY LAYER AND TURBULENT FLOW 9**

Development of flow in pipeline - Turbulent flow – Darcy's Weisbach equation – Colebrook White equation – Swamee and Jain equation - Hydraulic grade line – Total energy line – Flow through pipes – Pipes in series – Pipes in parallel – Boundary layers, Blasius solution, von-Karman momentum integral equation, boundary layer separation and control measures.

**UNIT V DIMENSIONAL ANALYSIS AND MODEL STUDY 9**

Dimensional analysis – Dimensional homogeneity – Rayleigh's method - ~~,~~ Buckingham's Pi theorem – Dimensionless numbers – Model laws – Similitude and model testing – Scale effect – Types of models – Analytical and physical model studies.

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES**

On completion of the course, the student is expected to be able to:

**CO1** Distinguish between the fluid properties and apply basic mathematical concepts of ~~vectors and~~ to fluid statics and kinematics.

**CO2** Formulate the integral equations for conservation laws from control volume perspective using RTT and to understand fluid dynamics.

**CO3** Solve problems of flow through pipes by applying concepts of laminar flow.

**CO4** Understand the characteristics of fluid flow in turbulent and upon the formation of boundary layer.

**CO5**~~.~~ Design and analyse the fluid flow model and to develop the physical model.

**REFERENCES:**


1.. Frank M. White and Henry Xue, Fluid Mechanics, 9th edition McGraw Hill, New York, 2022.
2. S K Som; Gautam Biswas and S Chakraborty, Introduction to Fluid Mechanics and Fluid Machines, Tata McGraw Hill Education Pvt. Ltd., 2012
3. Pani B S, Fluid Mechanics: A Concise Introduction, Prentice Hall of India Private Ltd, 2016
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6.. K.L. Kumar, Engineering Fluid Mechanics, (8th Ed.) S. Chand Publishing (India) Pvt. Ltd., New Delhi, 2016.
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**CO-PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | 1 | 2 | 2 | 1 | 2 |
| **CO2** | 3 | 1 | 3 | 3 | 3 | 3 |
| **CO3** | 3 | 2 | 3 | 3 | 3 | 2 |
| **CO4** | 3 | 2 | 3 | 3 | 3 | 3 |
| **CO5** | 3 | 2 | 3 | 3 | 3 | 3 |
| **Avg** | **3** | **2** | **3** | **3** | **3** | **3** |

• 1-low, 2-medium, 3-high

**HW3104 SURFACE WATER QUALITY MODELLING L T P C**
**3 0 4 5**

**UNIT I WATER QUALITY AND MATHEMATICAL INTERPRETATION 9**

Water quality problems – interpretation –Common way of modelling – Features of a mathematical model, Historical development of water quality models - Reaction Kinetics - Mass Balance, Steady-State Solution, and Response Time – Advection transport – dispersion transport- external contributions – ~~in~~ water transformations – non-conservative pollutants – hydrodynamic aspects.

**UNIT II MODELLING ENVIRONMENT - RIVERS, STREAMS AND ESTUARIES 9**

River hydrology – types – low-frequency analysis, dispersion, mixing, flow estimation, morphometry-travel time, depth, velocities – Mass balance – conservative and non-conservative substances, dispersion coefficient, pollutants in rivers - Estuary Transport- Net Estuarine Flow Estuary Dispersion Coefficient - Vertical Stratification

**UNIT III MODELLING ENVIRONMENT - LAKES, IMPOUNDMENTS, SEDIMENTS 9**

Lake Morphometry – Physical Processes - Water balance – steady state, temperature and stratification- lakes as mixed systems – lakes in series – Finite segment steady state lake model Sediment transport – suspended solids – bottom sediments- simple solids budgets – resuspension

**UNIT IV MODELLING ENVIRONMENT - EUTROPHICATION AND TEMPERATURE 9**

Basic mechanism –nutrients – N/p ratio - phosphorus loading concept – sediment-water interaction, heat budgets, thermal stratification, finite segment models – eutrophication control techniques, Control of DO level, Acidity and aquatic plants Significance of water temperature - sources and sinks – heat balance – temperature models – reduction of excess heat inputs

**UNIT V MODELLING ENVIRONMENT - WATERSHEDS 9**

Urban Watersheds - Sources of Pollution - Fate and Transport Processes - Stormwater Control Measures - Agricultural Watersheds - Sources of Pollution - Fate and Transport Processes - Best Management Practices

**TOTAL: 45 PERIODS**

**LIST OF EXPERIMENTS**

1 Introduction to the analytical laboratory. Good Laboratory Practices and Quality Control
2 Determination of physical parameters of the water
    a. Measurement of Temperature, Turbidity and Electrical Conductivity
3 Determination of Chemical parameters of water
    b. pH, Dissolved Oxygen, Total Solids
    c. Major ions - Sodium, potassium, chloride, fluoride, hardness, alkalinity
4. Calculation of Sodium Absorption Ratio
    d. Sodium and Magnesium
5. Calculation of residual sodium carbonates (RSC)
6. Determination of nutrients
    e. Nitrate and phosphate
7. Determination of Chlorophyll-a in water to understand the trophic status
8. Demonstration of Chlorophyll sonde
9. Demonstration of multiparameter water quality probes
10. Demonstration of BOD and COD estimations

**TOTAL : (45+ 60)=105 PERIODS**

**COURSE OUTCOMES**

**CO1** Comprehend the water quality problems and interpret them mathematically to develop models Analyse the physical, chemical and nutrients parameters through the analytical procedures

**CO2** Demonstrate the methodology for developing water quality models in the Environment of Rivers and streams. Examine the physical, chemical and nutrients parameters in respect to the standards

**CO3** Demonstrate the methodology for developing water quality models in the environment of lakes, impoundments and sediments. Demonstrate the usage of multiparameter probes, field kits and sondes for measuring water quality parameters

**CO4** Illustrate the mechanism of nutrient loading, its control and heat budget for temperature models

**CO5** Comprehend the differences among the numerical modelling methods in water quality modelling and also hands-on practice for water quality analysis

**REFERENCES**


1. Thomann, RV and Mueller JA, Principles of surface water quality modelling and control, Harper & Row, Publishers, New York, 1987
2. Steven C. Chapra, Surface Water Quality Modeling, McGraw-Hill International Editions, 2008
3. Marcello Benedini and George Tsakiris, Water Quality Modelling for Rivers and Streams, Springer Dordrecht Heidelberg New York London, 2013
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**CO-PO MAPPING**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 1 | 2 | 1 | 3 | 2 | 3 |
| **CO2** | 2 | 3 | 3 | 3 | 3 | 3 |
| **CO3** | 2 | 2 | 2 | 3 | 2 | 3 |
| **CO4** | 1 | 3 | 3 | 3 | 3 | 3 |
| **CO5** | 2 | 3 | 3 | 3 | 3 | 3 |
| **Avg** | **2** | **3** | **2** | **3** | **3** | **3** |

• 1-low, 2-medium, 3-high

**RM3151 RESEARCH METHODOLOGY AND IPR L T P C**
**2 1 0 3**

**UNIT I RESEARCH PROBLEM FORMULATION 9**

Objectives of research, types of research, research process, approaches to research; conducting literature review- information sources, information retrieval, tools for identifying literature, Indexing and abstracting services, Citation indexes, summarizing the review, critical review, identifying research gap, conceptualizing and hypothesizing the research gap

**UNIT II RESEARCH DESIGN AND DATA COLLECTION 9**

Statistical design of experiments- types and principles; data types & classification; data collection - methods and tools

**UNIT III DATA ANALYSIS, INTERPRETATION AND REPORTING 9**

Sampling, sampling error, measures of central tendency and variation,; test of hypothesis- concepts; data presentation- types of tables and illustrations; guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript; guidelines for writing thesis, research proposal; References – Styles and methods, Citation and listing system of documents; plagiarism, ethical considerations in research

**UNIT IV INTELLECTUAL PROPERTY RIGHTS 9**

Concept of IPR, types of IPR – Patent, Designs, Trademarks and Trade secrets, Geographical indications, Copy rights, applicability of these IPR; , IPR & biodiversity; IPR development process, role of WIPO and WTO in IPR establishments, common rules of IPR practices, types and features of IPR agreement, functions of UNESCO in IPR maintenance.

**UNIT V PATENTS 9**

Patents – objectives and benefits of patent, concept, features of patent, inventive steps, specifications, types of patent application; patenting process - patent filling, examination of patent, grant of patent, revocation; equitable assignments; Licenses, licensing of patents; patent agents, registration of patent agents.

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES**

Upon completion of the course, the student can

CO1: Describe different types of research; identify, review and define the research problem

CO2: Select suitable design of experiment s; describe types of data and the tools for collection of data

CO3: Explain the process of data analysis; interpret and present the result in suitable form

CO4: Explain about Intellectual property rights, types and procedures

CO5: Execute patent filing and licensing

**REFERENCES:**


1. Cooper Donald R, Schindler Pamela S and Sharma JK, “Business Research Methods”, Tata McGraw Hill Education, 11e (2012).
2. Soumitro Banerjee, “Research methodology for natural sciences”, IISc Press, Kolkata, 2022,
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**HW3201 ADVANCED HYDROLOGIC ANALYSIS AND DESIGN L T P C**

**3 0 0 3**

**UNIT I HYDROLOGIC SYSTEM AND STATISTICAL HYDROLOGY 10**

Hydrologic cycle – System concept – Hydrologic system Model – Classification of Hydrologic Models – Statistical, Stochastic and Deterministic Approaches – Random Variable - Statistical characteristics of Hydrological Data – Discrete and Continuous Probability distribution Functions - Probability density functions: measures of central tendency, dispersion and symmetry - Confidence intervals and hypothesis testing - Frequency and Return Period of Hydrologic Variables - Correlation Analysis – Developing Prediction Equation by Simple and Multiple Linear Regression – Reliability of the Model.

**UNIT II HYDROLOGIC TIME SERIES ANALYSIS 8**

Stochastic Process – Classification – Stationary and Non-Stationary Process – Time series – Classification – Component of Time series – Partial duration series - Method of Investigation – Auto Correlation Analysis – Moving Average Process – Auto Regressive Process - Auto Regressive Moving Average Process - Auto Regressive Integrated Moving Average Process – Thomas Fiering Model – Box Jenkins Model – Model formulation – Parameter Estimation – Calibration and Validation – Application to hydrologic Forecasting

**UNIT III DETERMINISTIC HYDROLOGIC SIMULATION 9**

Types of Deterministic Model – Black Box, Conceptual and Physically based models – Event based and continuous model – Models of IUH, Nash and Chow- Kulandaiswamy Models – Modelling Procedure, Calibration and Validation, Modelling Errors - HECHMS, SWAT, MIKE BASIN and MIKE SHE Models.

**UNIT IV HYDROLOGIC DESIGN 9**

Hydrologic Design Scale – Estimating Limiting Value – Hydrologic Design level – Design storms for Minor and Major structures - Hydrologic Design Data - Hydraulic Structure Design methods – Hydrologic Design Standard and Criteria – Hydro economic analysis - Hydrologic Risk, Reliability and Safety Factor - Computation of Design Storm - IDF Relationship - Estimation of PMP and PMF.

**UNIT V DESIGN FLOWS 9**

Estimation of Design Flows - Rational Method - Urban Storm Drainage Design – SWMM Model - Flood frequency analysis and hydrologic design under uncertainty - Hydrologic Design of Detention storage and Dam Spillway – Design of Culverts, Highway and Railway Bridges - Flood Control Reservoir Design – Water Supply Reservoir Design – Real Time Flood Forecasting.

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES:**

- On completion of the course, the student is expected to

**CO1** Describe the hydrologic modeling system and statistical analysis
**CO2** Apply the time series models for hydrologic forecasting
**CO3** Describe the classification of hydrologic models and the deterministic modeling approach of Hydrologic Simulation
**CO4** Compute the design storm by knowing the design concepts and methods
**CO5** Estimate the design flows for minor, medium and major hydraulic structures.

**REFERENCES:**

1.Ven Te Chow, D.R. Maidment and Lorry W. Mays, Applied Hydrology, McGraw Hill education, First edition, 2017.
2. V.P Singh, Hydrologic Systems, Prentice-Hall Englewood Cliffs, NJ 1989.
3.-P.Jayarami Reddy, Stochastic Hydrology, USP/Laxmi Publications (P) Ltd, New Delhi 2011.
4. W.J. Viessman and G.L. Lewis, Introduction to Hydrology, Fifth edition, Pearson Education, Inc.2008.
5. C.T.Haan, Statistical Methods in Hydrology Iowa State Press, 2002.
6. B.Sivakumar and R. Berndtsson, Advances In Data-based Approaches For Hydrologic Modeling and Forecasting, World Scientific Publishing Company, 2010

**CO-PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | 2 | 3 | 2 | 2 | 3 |
| **CO2** | 2 | 2 | 3 | 3 | 3 | 3 |
| **CO3** | 2 | 2 | 3 | 3 | 3 | 3 |
| **CO4** | 3 | 3 | 3 | 3 | 3 | 3 |
| **CO5** | 3 | 3 | 3 | 3 | 3 | 3 |
| **Avg** | **2** | **2** | **3** | **3** | **3** | **3** |

• 1-low, 2-medium, 3-high

**HW3202 GROUNDWATER MODELLING AND MANAGEMENT L T P C**
**3 0 0 3**

**UNIT I GROUNDWATER FLOW –ANALYTICAL AND ANALOG MODELS 9**

Analytical Solutions – Steady flow Isotropic / Anisotropic Confined Aquifer / Unconfined Aquifers – Flow net Analysis physical models – Computation of Discharge in Well Hydraulics – Transient Sand Tank Model – Electrical Analog Models – Steady State Regional flow.

**UNIT II GROUNDWATER FLOW – NUMERICAL MODELS 9**

Saturated Flow models -– Finite difference equations and solutions – Steady State and unsteady state – Regional and seepage flow models – Explicit methods - Implicit method - Alternating direction implicit – Crank Nicolson equation – Iterative methods -– Finite element method.

**UNIT III CONTAMINANT TRANSPORT MODEL 9**

Sources of Groundwater contamination - Contaminant transport theory – Advection, dispersion equation – Longitudinal and transverse dispersivity – Hydrodynamic dispersion of pollutants – Model Diffusion – Fick's Law -– Numerical simulation of solute transport – Tracer techniques to determine groundwater velocity – Determination of Dispersivity —- Tracer techniques to determine groundwater velocity - Numerical Simulation of Solute Transport - Numerical Dispersion Solution methods - Density driven flow - Heat transport.

**UNIT IV MODEL APPLICATIONS 9**

Data requirements – Conceptual model design: Conceptualization of aquifer system – Parameters, Input-output stresses, Initial and Boundary conditions - Model design and execution: Grid design, Setting boundaries, Time discretization and Transient simulation – Model calibration:steady state and unsteady state – sensitivity analysis – Model validation and prediction – Uncertainty in the model prediction – Groundwater Models

**UNIT V GROUNDWATER MANAGEMENT MODELS 9**

Optimal groundwater development – Indian GEC norms – Conjunctive use models Modeling multilayer groundwater flow system -Modeling contaminant migration – Modeling fracture flow system – Artificial recharge feasibility through modeling – Simulation of movements of solutes in unsaturated zone – Inverse Modelling of Groundwater flow - Stochastic modeling of groundwater flow - Groundwater contamination, restoration and management

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES:**

On completion of the course, the student is expected to be able to

**CO1** Applying the analytical and analog models for subsurface investigation of geological formations

**CO2** Develop the numerical models to study the groundwater movement and its potential using numerical methods.

**CO3** Explain the concepts of contaminant transport theory, numerical simulation of solute transport, solution methods for density driven flow and heat transport.

**CO4** Understanding the data requirements and conceptualization of the aquifer system for the better groundwater model development

**CO5** Apply the advance techniques in groundwater model for better management of groundwater resources.

**REFERENCES:**

1. M.P Anderson, and W.W. Woessner, *Applied Groundwater Modelling: Simulation of flowand*

*advective transport*, Academic Press, Inc., 2015
2. C.W. Fetter, *Contaminant Hydrogeology*, Prentice Hall, 2017
3. K.R. Rushton, *Groundwater Hydrology: Conceptual and Computational Models*, Wiley,2003
4. L. Elango and R. Jayakumar, *Modelling in Hydrology*, Allied Publishers Ltd., 2001
5. I. Remson, G.M. Hornberger and F.J. Moltz, *Numerical Methods in Subsurface Hydrology*,Wiley, New York, 1971

6. Robert Willis and William W.G.Yenth, *Groundwater System Planning and Management*,Prentice Hall, Englewood Cliffs, New Jersey, 1987.
7. Randall J.Charbeneau , *Groundwater Hydraulics and Pollutant Transport*, , Prentice Hall, 2000
8. K. Rastogi, *Numerical Groundwater Hydrology*, 2011

**CO-PO MAPPING**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 1 | 2 | 2 | 2 | 2 |
| **CO2** | 3 | 2 | 3 | 3 | 3 | 3 |
| **CO3** | 3 | 2 | 3 | 3 | 3 | 3 |
| **CO4** | 3 | 2 | 3 | 3 | 3 | 3 |
| **CO5** | 3 | 2 | 3 | 3 | 3 | 3 |
| **Avg** | **3** | **2** | **3** | **3** | **3** | **3** |

• 1-low, 2-medium, 3-high

**HW3203 OPEN CHANNEL HYDRAULICS L T P C**
**3 0 0 3**

**UNIT I BASIC PRINCIPLES 9**

Introduction to open channel flow (Types of flow, channel geometry, pressure distribution, effect of viscosity and gravity, non-uniformity in velocity distribution, kinetic correction factor and momentum correction factor) – Difference between pressure flow in pipe and open channel flow – System and control volume analysis – Reynold's transportation theorem for open channel – Equations of continuity, energy and momentum for an open channel flow.

**UNIT II UNIFORM FLOW 9**

Uniform flow – Derivation of Chezy's and Manning's equation from momentum principle – Flow resistance – Channel roughness (including channels with composite roughness) – Uniform flow computations – Specific energy – Critical depth – Calculation of critical depth - Hydraulically efficient sections – Channel transitions (both vertical and horizontal).

**UNIT III GRADUALLY AND RAPIDLY VARIED FLOW 9**

GVF – Dynamic equation – Classification of GVF profiles – Computation of GVF profiles – Direct step method – Standard step method – Control sections - Break in grades – Specific force – Application of momentum equation to RVF - Hydraulic jump – Sequent depth ratio – Types of hydraulic jumps - Energy loss in stilling basin – Location of jump.

**UNIT IV SPATIALLY VARIED AND UNSTEADY FLOW 9**

Spatially varied flow (SVF) – Derivation of equation – SVF with increasing discharge and decreasing discharge – Unsteady flow – Classifications – Gradually varied unsteady flow - St. Venant equation – Uniformly progressive wave – Rapidly varied unsteady flow Positive and negative surges – Applications.

**UNIT V FLOW MEASURMENTS AND HYDRAULIC MODELLING 9**

Flow measurements in open channel – Sharp crested weir – Board crested weir – Parshall flume – Cut throat flume – Stage discharge relationship – Instruments for flow measurements – Physical modelling in hydraulics – Dimensional analysis – Model studies – Froude model law – Distorted models – River model.

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES**

On completion of the course, the student is expected to be able to:

**CO1** Illustrate the concepts of open channel flows vis-a-vis closed conduct flow and design channel transitions and stilling basins.

**CO2** Calculate the discharge for open channel appurtenances like weir and flumes. Formulate the non-dimensional variables using dimensional analysis.

**CO3** Compute uniform flows using iterative and or Newton Raphson technique. Calculate the flow resistance using fluid mechanics concepts of turbulent flows.

**CO4** Demonstrate the use of governing equations to classify gradually varied flow profiles and compute the same using numerical methods.

**CO5** Formulate the one-dimensional unsteady flow equations and solve using method of characteristics. Appraise the use of software like HEC-RAS.

**REFERENCES:**


1. Sturm T.W., Open Channel Hydraulics – Tata-McGraw Hill 2nd edition, New Delhi 2011.
2. Subramanya K., Flow in Open Channels (4th ed.) Tata McGraw Hill, New Delhi 2015.
3. Srivastava R. Flow through Open Channels Oxford University Press New Delhi, 2008.
4. Chaudhry M. H., Open Channel Flow. Prentice Hall of India, Eastern Economic Edition, New Delhi, 1994,
5. Hubert Chanson, The Hydraulics of Open Channel Flow: An Introduction, 2nd Ed.,Elsevier, Butterworth-Heinemann Publishing, 2004.
6. Chow Ven-te Open Channel Hydraulics McGraw Hill, New York NY 1959.
7. French, R. H., Open Channel Hydraulics McGraw Hill, New York NY 1985.


**CO-PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | 1 | 2 | 2 | 1 | 2 |
| **CO2** | 2 | 1 | 3 | 3 | 2 | 2 |
| **CO3** | 3 | 2 | 3 | 3 | 2 | 3 |
| **CO4** | 3 | 2 | 3 | 3 | 3 | 3 |
| **CO5** | 3 | 2 | 3 | 3 | 3 | 3 |
| **Avg** | **3** | **2** | **3** | **3** | **2** | **3** |

• 1-low, 2-medium, 3-high

**HW3204 SYSTEMS ANALYSIS IN WATER RESOURCES L T P C**
**3 0 4 5**

**UNIT I SYSTEM CONCEPTS 9**

Definition, classification, and characteristics of systems - Scope and steps in systems engineering – General Systems Theory by Kenneth Boulding - Need for systems approach to water resources and irrigation.

**UNIT II LINEAR PROGRAMMING 9**

History of operations research - Linear programming, problem formulation, graphical solution, solution by simplex method - Sensitivity analysis, application to design and operation of reservoir, single and multipurpose development plans - Case studies.

**UNIT III DYNAMIC PROGRAMMING 9**

Bellman's optimality criteria, problem formulation and solutions - Application to design and operation of reservoirs, Single and multipurpose reservoir development plans – Capacity expansion for reservoir planning - Case studies.

**UNIT IV SIMULATION 9**

Basic principles and concepts - Random variant and random process - Monte Carlo techniques - Model development - Different Operating Policies – Rule Curve Development - Single and multipurpose reservoir simulation models - Case studies.

**UNIT V ADVANCED OPTIMIZATION TECHNIQUES 9**

Integer and parametric linear programming - Goal programming models with applications - Discrete differential dynamic programming and incremental dynamic programming – Linear decision rule models with application - Stochastic dynamic programming models - application of machine learning algorithms to reservoir release optimization

**TOTAL: 45 PERIODS**

**LIST OF EXPERIMENTS**

1. Model the following data analysis and creating SPSS tables and descriptive statistics
2. Model development of a Water supply and Storm water management system.
3. Hydrologic model analysis using HEC HMS
4. River analysis for flood inundation in a river basin using HEC-RAS/Mike-Hydro packages.
5. Application of Machine learning algorithm for rainfall runoff relationship using Python Programming Library functions.
6. Design and simulation of ground water flow model using Visual MODFLOW
7. Creating a Ground water Mass transport model to remediate the ground water pollution
8. Land use and land cover classification and projection using Image processing tools available in QGIS.
9. Hydraulic simulation of river flow using flow 3D.
10. Development of simulation model for soil water balance using SWAT-QGIS

**TOTAL: 45 +60=105 PERIODS**

**COURSE OUTCOMES:**

- On completion of the course, the student is expected to be able to:

**CO1** Define the system concept and steps in systems approach for the water resources engineering describe the basics of computing techniques with solution process involved in real field problems.

**CO2** Apply the knowledge of optimisation techniques such as Linear programming and simplex method for reservoir operation. create the data base structure with modern data analytics along with soft computing methods like machine learning and Fuzzy logic classification procedures

**CO3** Explain single and multipurpose reservoir optimisation using dynamic programming Design the water supply network and storm water management techniques and evaluate the system performance using available open-source software

**CO4** Develop the simulation model based on deterministic and stochastic simulation for reservoir operating policy Demonstrate the hydrological extreme events through hydrological and hydraulic models

**CO5** Apply the creative and advance optimisation techniques like goal programming, heuristic algorithm in the field of water planning and management.
Formulate the methodology to solve the emerging problems through readymade software to suit for the regional or site-specific conditions.

**REFERENCES:**

1. Vedula, S., and Majumdar, P.P. Water Resources Systems – Modeling Techniques and Analysis Tata McGraw Hill, New Delhi, Fifth reprint, 2010.
2. Gupta, P.K., and Man Mohan, “Problems in Operations Research”, (Methods and Solutions), Sultan Chand and Sons, New Delhi, 1995.
3. Chaturvedi, M.C., “Water Resources Systems Planning and Management”, Tata McGraw Hill, New Delhi, 1997.
4. Taha, H.A., “Operations Research”, McMillan Publication Co., New York, 1995.
5. Taha, H.A., “Operations Research”, Pearson Prentice Hall, Seventh Edition, 2007
6. Hiller, F.S., and Liebermann, G.J., “Operations Research”, CBS Publications and Distributions, New Delhi, 1992.
7. Aliev R. A, and Aliev Rashad, "Soft Computing and its Applications", World Scientific Publications Co. Pte. Ltd. Singapore, 2017.
8. Stephen Marsland, “Machine Learning – An Algorithmic Perspective”, Chapman and Hall, CRC Press, Second Edition, 2014.
9. Sridhar S, “Digital Image Processing”, Oxford University Press, New Delhi, 2011.
10. Thomas Cannolly and Carolyn Begg, “Database Systems, A Practical Approach to Design, Implementation and Management”, Third Edition, Pearson Education, 2007
11. Joel Lawhead, QGIS Python Programming Cookbook - Second Edition, Kindle Edition,2017.
12. John E. Gribbin, Introduction to hydraulics and hydrology with applications for Storm water Management. DELMAR, Thomson Learning, USA,2002.
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14. Hydrologic Engineering Center, HEC-RAS River Analysis system, Hydraulic Reference Manaual, CPD-69. U.S. Army Corps of Engineers, Hydrologic Engineering Center, 609 Second Street, Davis, CA, 2014
15. Jothiprakas, Natarajan and R Murulidharan - A Case study on Pipe Network Analysis in Educational Campus, Journal of Indian water works Association, Vol. XXXXII No 2. 2010

**CO-PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 1 | 2 | 1 | 2 | 1 |
| **CO2** | 3 | 1 | 3 | 2 | 1 | 1 |
| **CO3** | 3 | 1 | 3 | 3 | 2 | 2 |
| **CO4** | 3 | 2 | 3 | 3 | 3 | 3 |
| **CO5** | 3 | 3 | 3 | 3 | 3 | 3 |
| **Avg** | **3** | **1** | **3** | **3** | **2** | **2** |

• 1-low, 2-medium, 3-high

**HW3251 REMOTE SENSING AND GIS FOR WATER RESOURCES L T P C**
**3 0 4 5**

**UNIT I BASICS OF REMOTE SENSING 9**

Physics of remote sensing, Types of Remote sensing, electromagnetic radiation (EMR), Interaction of EMR with atmosphere, earth surface, soil, water and vegetation; Swath, Nadir, resolutions, image referencing system; Monitoring atmosphere, land and water resources - Indian Space Programme, Sensor characteristics LANDSAT, SPOT, ERS, IKONOS, IRS and others - Principles of LiDAR Remote Sensing - LiDAR Data Processing- LiDAR applications.

**UNIT II INTERPRETATION AND ANALYSIS 9**

Remote sensing data products – Visual image interpretation – interpretation keys; data formats of digital image - Digital image processing – Image preprocessing – Image enhancement – Image transformation – image classification – accuracy assessment - Data merging.

**UNIT III GEOGRAPHIC INFORMATION SYSTEM 9**

Definition – Basic components of GIS – Map projections and coordinate system – Spatial data structure: raster, vector – Spatial Relationship – Topology – Geodatabase models: hierarchical, network, relational, object-oriented models – Data Encoding methods – encoding raster data, vector data and attribute data, linking spatial and attribute data- Integrated GIS database -common sources of error – Data quality: Macro, Micro and Usage level components - Meta data - Spatial data transfer standards.

**UNIT IV GEOSPATIAL ANALYSIS 9**

Thematic mapping – Geospatial Measurements, query analysis, buffering, overlay operations, network analysis, DEM, DSM, DTM, Interpolation - Geovisualisation - Object oriented GIS – Modern trends of GIS – WebGIS, 3DGIS, Real-time GIS.

**UNIT V WATER RESOURCES APPLICATIONS 9**

Water resources models – Rainfall-runoff modelling – Groundwater modelling – Water quality modelling - Flood inundation mapping and modelling – Drought monitoring – Cropping pattern change analysis - Site selection for artificial recharge - Reservoir sedimentation - Case studies – Drones in irrigation and agriculture

**TOTAL: 45 PERIODS**

**LIST OF EXPERIMENTS**

**Image processing**

1. Satellite data products: commercial and open source
2. Land use land cover classification
    1. Unsupervised
    2. Supervised
    3. Accuracy assessment
3. Vegetation indices for vegetative cover analysis
4. Reservoir volume estimation using temporal satellite imageries

**Geographical Information System**

5. Georeferencing of toposheet and creating vector layers, attribute tables and layout preparation
6. GPS Survey, data transformation into GIS, analysis of data and creation of maps using Google earth maps.
7. Use of D8 pointer algorithm for deriving flow direction, flow accumulation and watershed delineation.
8. Interpolation of point data to create Spatial Maps.
    1. Theisson polygon method
    2. Natural Neibourhood method
    3. Triangular irregular network
    4. Kriging method
9. Derivation of integrated map using weighted overlay techniques (anyone).
    1. Identifying suitable artificial recharge areas
    2. Identification of ground water potential zones
    3. Estimation of sedimentation yield using RUSLE method
10. Join and Relate tables, File conversion from .kml to.shp
11. Open source GIS –Demo

**TOTAL: (45+60) = 105 PERIODS**

**COURSE OUTCOMES**

On completion of the course, the student is expected to

**CO1** Describe the principles of remote sensing and distinguish the sensors and satellite's characteristics for different applications Demonstrate the methodology for image classification and interpretation using remote sensing

**CO2** choose the appropriate data products and techniques for image analysis Illustrate the basics of map preparation, watershed delineation and geospatial data analysis techniques in GIS attribute creation

**CO3** Illustrate the basics of map preparation in GIS Formulate the methodology using remote sensing and GIS tools for various applications in water resources engineering

**CO4** Demonstrate the geospatial data analysis techniques

**CO5** Formulate the methodology using remote sensing and GIS tools for various applications in water resources engineering

**REFERENCES**


1. B. Bhatta, *Remote Sensing and GIS*, 2nd ed, Oxford University Press, New Delhi, 2011
2. T.M. Lillesand and R.W. Kiefer, *Remote Sensing and Image Interpretation*, 7th ed, John Wiley and Sons, New York, February 2015
3. P.A. Burrough and R.A. McDonnell, *Principles of Geographical Information Systems*, 3rd Edition, Oxford University Press, New York, 2016
4. Ian Heywood Sarah, Cornelius and Steve Carver, *An Introduction to Geographical Information Systems*, Pearson Education, New Delhi, 2002.
5. G. Joseph and C. Jeganathan, *Fundamentals of Remote Sensing*, 3rd ed, Universities Press Pvt. Ltd., Hyderabad, India, 2018.
6. Pinliang Dong and Qi Chen, "LiDAR Remote Sensing and Applications" CRC Press Taylor & Francis Group, 2018
7. T.M. Lillesand and R.W. Kiefer, *Remote Sensing and Image Interpretation*, 3rd ed, John Wiley and Sons, New York,1993.
8. P.A. Burrough and R.A. McDonnell, *Principles of Geographical Information Systems*, Oxford University Press, New York,1998.


**CO-PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 2 | 3 | 2 | 3 |
| **CO2** | 2 | 2 | 2 | 3 | 3 | 3 |
| **CO3** | 1 | 1 | 2 | 3 | 2 | 3 |
| **CO4** | 2 | 2 | 2 | 3 | 3 | 3 |
| **CO5** | 3 | 3 | 3 | 3 | 3 | 3 |
| **Avg** | **2** | **2** | **2** | **3** | **3** | **3** |

• 1-low, 2-medium, 3-high

**HW3311** **PRACTICAL TRAINING (4 Weeks)** **L T P C**
**0 0 0 2**

**SYLLABUS:** The students individually undertake training in reputed institutions doing Water Resources Engineering with a special focus on Hydrology and Water Resources Engineering during the summer vacation for a specified duration of four weeks. At the end of the training, a detailed report on the work done. The students will be evaluated through a viva-voce examination by a three-member committee.

**COURSE OUTCOME:**

- On completion of the course, the student is expected to be able to

CO1 Get expose to the real-world problems
CO2 Describe the challenges in the management of water resources
CO3 Develop skills for solving the problem
CO4 Present the work carried out during the practical training

**CO - PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | - | 2 | 2 | 2 | 2 |
| **CO2** | 2 | - | 2 | 3 | 2 | 2 |
| **CO3** | 3 | - | 3 | 3 | 2 | 2 |
| **CO4** | - | 3 | - | - | - | 2 |
| Avg | **2** | **3** | **2** | **3** | **2** | **2** |

• 1-low, 2-medium, 3-high

**HW3312** **PROJECT WORK I** **L T P C**
**0 0 12 6**

**SYLLABUS:**

The student individually works on a specific topic approved by faculty member who is familiarin the area of interest. The student can select any topic which is relevant to his/her specialization. The topic may be experimental or analytical or case studies. At the end of the semester, a detailed report on the work done should be submitted, which contains clear definition of the identified problem, detailed literature review related to the area of work and methodology for carrying out the work. The students will be evaluated through a viva-voce examination by a panel of examiners including one external examiner.

**TOTAL: 180 PERIODS**

**COURSE OUTCOME:**

- On completion of the course, the student is expected to be able to

CO1 apply the knowledge gain from the theoretical and practical courses to the real-world problems.
CO2 identify the gap in research by doing extensive literature survey.
CO3 formulate the methodology for arriving at the solution.
CO4 Interpret and present the findings of the research work carried out
CO5 Synthesize the conclusion of the research
CO5 Present the research work carried out during project work I

**CO - PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO1 | 2 | - | 2 | 2 | 2 | 2 |
| CO2 | 3 | - | 2 | 3 | 2 | 2 |
| CO3 | 3 | - | 3 | 3 | 2 | 2 |
| CO4 | 3 | - | 3 | 3 | 2 | 3 |
| CO5 | 3 | - | 3 | 3 | 2 | 3 |
| CO6 | - | 3 | - | - | - | 2 |
| Avg | **3** | **3** | **3** | **3** | **2** | **2** |

• 1-low, 2-medium, 3-high

**HW3411** **PROJECT WORK II** **L T P C**
**0 0 24 12**

**SYLLABUS:**

The student should continue the Project work I on the selected topic as per the formulated methodology. At the end of the semester, after completing the work to the satisfaction of the supervisor and review committee, a detailed report should be prepared and submitted to the head of the department. The students will be evaluated based on the report and the viva-voce examination conducted by a panel of examiners including one external examiner.

**TOTAL: 360 PERIODS**

**COURSE OUTCOME:**

- On completion of the course, the student is expected to be able to

CO1 apply the knowledge gain from the theoretical and practical courses to the real-world problems.

CO2 identify the gap in research by doing extensive literature survey.
CO3 formulate the methodology for arriving at the solution.
CO4 Interpret and present the findings of the research work carried out
CO5 Synthesize the conclusion of the research
CO6 Present the research work carried out during project work II

**CO - PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| CO1 | 2 | - | 2 | 2 | 2 | 2 |
| CO2 | 3 | - | 2 | 3 | 2 | 2 |
| CO3 | 3 | - | 3 | 3 | 2 | 2 |
| CO4 | 3 | - | 3 | 3 | 2 | 3 |
| CO5 | 3 | - | 3 | 3 | 2 | 3 |
| CO6 | - | 3 | - | - | - | 2 |
| Avg | **3** | **3** | **3** | **3** | **2** | **2** |

• 1-low, 2-medium, 3-high

## PROFESSIONAL ELECTIVE COURSES

**HW3001 FLOOD MODELLING AND DROUGHT MANAGEMENT L T P C**
**3 0 0 3**

**UNIT I FLOOD ESTIMATION 9**

Hydrologic extremes – Flood – Types of Flood – Effects of Flood – Design Flood - SPF/MPF Estimation of design flood – Physical Indicators - Envelope curves - Empirical methods – Rational method - Statistical methods – Frequency analysis – Unit hydrograph method – Synthetic Unit hydrograph method.

**UNIT II FLOOD MODELLING AND MANAGEMENT 9**

Hydrologic and Hydraulic Routing – Reservoir and Channel Routing - 1D and 2D Flood Inundation Modelling – HEC HMS and HEC RAS software - Flood control methods – Structural and non structural measures - Flood Plain Zoning – Flood forecasting and warning, managing flood emergencies – Flood Mitigation - Remote Sensing and GIS for Flood modelling and management - Flood Control and its Status in India – Floods under changing climate.

**UNIT III DROUGHT AND IMPACTS 9**

Definition – Definitions based on rainfall, stream flow, vegetation and comprehensive aspects - Characterisation of Drought/water shortage/aridity/desertification - Types of Drought – NCA classification – Drought: Climatological and human-induced causes - Impacts of Drought – Environmental, Social and Economical aspects – Drought in a changing climate – Heat waves and agricultural drought.

**UNIT IV DROUGHT ASSESSMENT 9**

Drought indicators - Drought Severity Assessment – Meteorological, Hydrological and Agricultural methods – Drought Indices – GIS based Drought Information system – Drought Vulnerability Assessment and Mapping Using GIS - Climate change and Drought: frequency and temporal trends.

**UNIT V DROUGHT MONITORING AND MANAGEMENT 9**

DPAP Programme - Drought Monitoring - Application of Remote sensing – Drought Mitigation – Proactive and Reactive Approach – Supply and Demand Oriented Measures – Long term and Short term Measures – Climate change and Water Scarcity Management in Urban, Industrial and Agricultural sectors – Drought forecasting - Drought preparedness and action plan.

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES:**

- On completion of the course, the student is expected to

**CO1** Perform design flood estimation using different methods.
**CO2** Explain different flow routing methods and suggest suitable flood control measures.
**CO3** Describe different types of drought and their impacts
**CO4** Comprehend different indices and methods used for drought assessment.
**CO5** Discuss the various approaches of Drought mitigation and water scarcity management

**REFERENCES:**


1.Ven Te Chow, D.R. Maidment and Lorry W. Mays, Applied Hydrology, McGraw Hill education, First edition, 2017.
2. Vijay P.Singh., Elementary Hydrology, Prentice Hall of India, New Delhi, 1994.
3. V. Yevjevich, Drought Research Needs, Water Resources Publications, Colorado State University, USA, 1977.
4. V. Rangapathy, M. Karmegam and R. Sakthivadivel, Monograph in Flood Routing Methods as Applied to Indian Rivers, Anna University Publications.
5. National Disaster Management Guidelines: Management of Drought (2010), A publication of the National Disaster Management Authority, Government of India. ISBN 978-93-80440-08-8, September 2010, New Delhi.
6. Handbook of Drought Indicators and Indices. WMO/GWP Integrated Drought Management Programme (IDMP). 2016. WMO-No. 1173. WMO, Geneva, Switzerland and GWP, Stockholm, Sweden.


**CO-PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 3 | 3 | 3 | 3 |
| **CO2** | 3 | 3 | 3 | 3 | 3 | 3 |
| **CO3** | 1 | 1 | 2 | 2 | 3 | 3 |
| **CO4** | 2 | 2 | 3 | 3 | 3 | 3 |
| **CO5** | 3 | 3 | 3 | 3 | 3 | 3 |
| **Avg** | **2** | **2** | **3** | **3** | **3** | **3** |

• 1-low, 2-medium, 3-high

**IW3051 WATERSHED CONSERVATION AND MANAGEMENT L T P C**
**3 0 0 3**

**UNIT I WATERSHED CONCEPTS 9**

Watershed – Definition, Need and Elements – Principles - Influencing Factors: Geology – Soil – Morphometric analysis - Toposheet - Delineation – Codification – Prioritization – Watershed Atlas.

**UNIT II SOIL CONSERVATION MEASURES 9**

Types of Erosion – Water and Wind Erosion: Causes, Factors, Effects and Control – Soil Conservation Measures: Agronomical and Mechanical – Design of Terraces and Bunds - Estimation of Soil Loss – USLE Modified and Revised USLE - Sedimentation.

**UNIT III WATER HARVESTING AND CONSERVATION 9**

Yield from a Catchment -Traditional Water Harvesting Techniques – Micro-Catchments - Design of Small Water Harvesting Structures — Farm Ponds — Percolation Tanks — Check dams — Grassed Waterways.

**UNIT IV GIS FOR WATERSHED MANAGEMENT 9**

Applications of Remote Sensing and Geographical Information System - Role of Decision Support System — Conceptual Models and Case Studies.

**UNIT V WATERSHED MANAGEMENT 9**

Project Proposal Formulation - Watershed Development Plan – Entry Point Activities – Watershed Economics - Agroforestry – Grassland Management – Wasteland Management – Watershed approach in Government Programmes – People's Participation – Evaluation of Watershed Management programme – Integrated Watershed Management – Case studies.

**TOTAL: 45 PERIODS**

**COURSE OUTCOME:**

- On completion of the course, the student is expected to be able to

**CO1** Recognize and interpret the morphological features of a watershed and describe the principles of watershed management.
**CO2** State, design and sketch the soil conservation structures.
**CO3** Describe the micro catchment and apply the concepts to design the small waterharvesting structures.
**CO4** Illustrate the application of modern tools and technology in the management of watershed.
**CO5** Classify the management activities and to develop an integrated watersheddevelopment plan.

**REFERENCES:**


1. Glenn O. Schwab, Soil and Water Conservation Engineering, John Wiley and Sons, 1981.
2. Suresh, R. Soil and Water Conservation Engineering, Standard Publication, New Delhi,1982.
3. Heathcote, I. W. Integrated Watershed Management: Principles and Practice. John Wileyand Sons, Inc., New York, 1988.
4. Ghanashyam Das, Hydrology and Soil Conservation Engineering, Prentice Hall of India Private Limited, New Delhi, 2000.
5. Vir Singh, Raj, Watershed Planning and Management, Yash Publishing House, Bikaner,2000.


**CO – PO MAPPING**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | 2 | 2 | 3 | 3 | 3 |
| **CO2** | 3 | 1 | 3 | 3 | 2 | 3 |
| **CO3** | 3 | 2 | 3 | 3 | 3 | 3 |
| **CO4** | 2 | 2 | 3 | 3 | 2 | 3 |
| **CO5** | 3 | 3 | 2 | 2 | 3 | 3 |
| **Avg** | **3** | **2** | **3** | **3** | **3** | **3** |

• 1-low, 2-medium, 3-high

**IW3052 CLIMATE CHANGE AND WATER RESOURCES LT P C**
**3 0 0 3**

**UNIT I GLOBAL CLIMATE SYSTEM 9**

Climate - Drivers of Climate change - Components of Global Climate System: Atmosphere, hydrosphere, Lithosphere, cryosphere and biosphere, atmospheric circulation- redistribution of heat; Global Energy Balance: Greenhouse effect; Hydrological cycle: Reservoirs, flows (or Fluxes), Residence Times, Water Vapor

**UNIT II CLIMATE VARIABILITY AND CHANGE 9**

Climate variability and change: Factors Responsible for Natural Climate Variability and Change: large scale variability - El Nino, La Nina — ENSO, Teleconnections, Sun-Moon-Earth interaction - Factors Responsible for Anthropogenic Climate Change, Detection and Attribution of Climate Change; Global and Indian Scenarios — Observed changes and projected changes of IPCC - Impacts on water resources – IPCC Scenarios

**UNIT III CLIMATE MODELS 9**

Need for vulnerability assessment - Approaches for assessment — Types of climate models, History of climate modelling, Sensitivity of climate models, parameterization of climate process, simulation. Box models - Zero-dimensional models - Radiative-convective models - Higher- dimension models - EMICs (Earth-system models of intermediate complexity) - GCMs (global climate models or general circulation models) — Regional Models - Sectoral models – CMIP - Selection of Global Climate Models- Performance Indicators for Evaluating GCMs

**UNIT IV ADAPTATION AND MITIGATION 9**

Water-related adaptation to climate change in the fields of Ecosystems and biodiversity, - Agriculture and food security, land use and forestry, Human health, water supply and sanitation, infrastructure and Economy (insurance, tourism, industry and transportation) - Adaptation, vulnerability and sustainable development Sector-specific mitigation - Carbon dioxide capture and storage (CCS), Bio-energy crops, Biomass electricity, Hydropower, Geothermal energy, Energy use in buildings, Land-use change and management, Cropland management, Afforestation and Reforestation.

**UNIT V IMPACTS ON WATER RESOURCES 9**

General Circulation Models – downscaling – statistical downscaling – dynamic downscaling.
Case studies on impacts of climate change on Water resources assessment, water quality, groundwater, irrigation and agriculture

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES**

**CO1** Describe the earth's climate system and the interaction among the subsystems of the earth's components

**CO2** Illustrate the basics of climate variability and change including the observations and projections

**CO3** Demonstrate the climate models for vulnerability assessment at global and at regional scale

**CO4** Describe the options available for adaptation and mitigation for different sectors

**CO5** Comprehend the methodology for using appropriate datasets for an impact assessment on Water resources assessment, water quality, groundwater, irrigation and agriculture through case studies

**REFERENCES**


1. Sangam Shrestha, Mukand S. Babel and Vishnu Prasad Pandey," Climate Change and Water Resources", CRC Press an imprint of the Taylor & Francis Group, 2014
2. John M. Wallace and Peter V. Hobbs, "Atmospheric Science: An Introductory Survey", Second Edition, Academic Press an imprint of Elsevier, 2006
3. David Neelin., J, "Climate Change and Climate Modeling", University Press, Cambridge, United Kingdom, 2011
4. McGuffie., K, and Henderson-Sellers.A, "A Climate Modelling Primer", Third Edition, John Wiley & Sons, Ltd, 2005
5. Thomas T. Warner, "Numerical Weather and Climate Prediction", Cambridge University Press, New York, 2011

6. Intergovernmental Panel on Climate Change: https://www.ipcc.ch/
7. Komaragiri Srinivasa Raju and Dasika Nagesh Kumar, Impact of Climate Change on Water Resources With Modeling Techniques and Case Studies, Springer Climate, 2018

**CO-PO MAPPING**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 1 | 2 | 2 | 3 | 2 | 3 |
| **CO2** | 2 | 3 | 3 | 3 | 3 | 3 |
| **CO3** | 2 | 3 | 3 | 3 | 2 | 3 |
| **CO4** | 2 | 2 | 3 | 3 | 3 | 3 |
| **CO5** | 3 | 2 | 3 | 3 | 3 | 3 |
| **Avg** | **2** | **2** | **3** | **3** | **3** | **3** |

• 1-low, 2-medium, 3-high

**HW3051 ENVIRONMENTAL IMPACT ASSESSMENT FOR WATER RESOURCES**

**L T P C**
**3 0 0 3**

**UNIT I ENVIRONMENTAL ISSUES** **9**

Water resources development and environmental issues – Environment in water resources project planning – Environmental regulations and requirements – EIA notification - Role of EIA

**UNIT II EIA FUNDAMENTALS** **9**

Environmental Impact Assessment (EIA) – EIA in Project Cycle – Legal and Regulatory aspects in India according to Ministry of Environment and Forests – Types and limitations of EIA – Cross sectoral issues and terms of reference in EIA – Public hearing - Merits and Demerits of EIA

**UNIT III ENVIRONMENTAL BASELINEAND IMPACT STUDIES** **9**

Baseline Data - Methodologies of EIA - Semi-quantitative methods: Ad hoc Methods - Check lists - Network and matrix methods -Overlay - Cost benefit analysis – Analysis of alternatives – Hydrological and water quality impacts – Ecological and biological impacts – Social and cultural impacts – Soil and landscape changes – Agro economic issues – Human health impacts – Ecosystem changes - Cumulative impact assessment

**UNIT IV EIA REPORT** **9**

EIA team formation - Environmental management plan – Mitigation and rehabilitation plans – Policy and Guidelines for planning and monitoring programmes – Post project audit – Documentation of EIA findings – Ethical and quality aspects of EIA

**UNIT V EIA CASE STUDIES** **9**

EIA of water resources projects – Case studies – Hydropower projects – Command area problems - Role of NGOs - Digital EIA

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES:**

- On completion of the course, the student is expected to be able to

**CO1** Understand the complex socio-ecological issues in developmental projects.
**CO2** Analyse the tools of environmental impact in both the qualitative and quantitative terms
**CO3** Apply the domain knowledge and legal principles, access to information, public participation.

**CO4** Communicate research findings effectively through written, media materials and colloquial in public hearing for project based EIA.

**CO5** Analyse and evaluate the evidences, arguments, claims, beliefs on the basis of empirical evidence.

**REFERENCES:**


1. B. Chari, Richa Sharma and S.A. Abbasi, *Comprehensive Environmental Impact Assessment of Water Resources Projects: With Special Reference to Sathanur Reservoir Project (Tamil Nadu)/K*, Discovery Pub., New Delhi, 2005.
2. John Glasson, *Introduction to Environmental Impact Assessment*, 2nd Edition Taylor & Francis e-book, 2005.
3. D.P. Lawrence, *Environmental Impact Assessment – Practical solutions to recurrent problems*, Wiley-Inter Science, New Jersey. 2003.
4. N. Arnel, Hydrology and global environmental change, Prentice Hall, Harlow, 2002.
5. R.R. Barathwal, *Environmental Impact Assessment*, New Age International Publishers, New Delhi. 2002.
6. UNEP's *Environmental Impact Assessment Training Resource Manual*, Second Edition, 2002.
7. Petts, *Handbook of Environmental Impact Assessment*, Vol., I and II, Blackwell Science London, 1999.
8. L.W. Canter, *Environmental Impact Assessment*, McGraw Hill International Edition, New York. 1995.


**CO-PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 1 | 2 | 2 |
| **CO2** | 2 | 2 | 2 | 2 | 3 | 2 |
| **CO3** | 2 | 2 | 2 | 2 | 3 | 3 |
| **CO4** | 2 | 3 | 3 | 3 | 3 | 3 |
| **CO5** | 3 | 3 | 3 | 3 | 3 | 3 |
| **Avg** | **2** | **2** | **2** | **3** | **3** | **3** |

• 1-low, 2-medium, 3-high

**HW3002 URBAN WATER RESOURCES MANAGEMENT L T P C**
**3 0 0 3**

**UNIT I URBAN ECOSYSTEM 9**

Cities as Ecological system – hybrid ecosystem – Resilience in urban ecosystem. Human components of Ecosystem – Urban pattern and Ecosystem function. Population and Community dynamics, functions of Urban Ecosystem.

**UNIT II URBAN HYDROLOGY 9**

The urban hydrological cycle – Function – Human induced changes in urban watershed – Hydrological calculation – Runoff – Infiltration – hydrograph.

**UNIT III URBAN STORM WATER MANAGEMENT 9**

Design of Drainage System – Roadway Drainage Analysis – Code provisions - Types of inlets – inlet design – Design of storm drain, Hydraulic design of culverts, Erosion control. Storm water management regulations - structural storm management systems – Newer trends in storm water management (Green infrastructure) – installation – operation and maintenance – demo of SWMM.

**UNIT IV WATER CONSERVATION AND REUSE 9**

Trends in supply and demand – indoor conservation – outdoor conservation – water reuse –

rainwater harvesting – types – evaluation - public education.

**UNIT V WATER GOVERNANCE AND GOOD PRACTICES 9**

Challenges in water sector - Institutional setting, Supply-demand management, Waste water management – Private sector participation, Urban service delivery, Customer satisfaction, financial resource management – Case studies of best practices in cities across the world and India.

**TOTAL : 45 PERIODS**

**COURSE OUTCOMES:**

- On completion of the course, the student is expected to

**CO1** Explain various functional elements of urban ecosystem.
**CO2** Calculate urban runoff, compute supply and demand of water,draw hydrograph
**CO3** Design a suitable storm water system and apply the newer techniques of green infrastructure
**CO4** Explain the different conservation techniques and reuse of water in urban areas
**CO5** Propose best management practices for Indian context and across the world

**REFERENCES:**


1. Anand Chiplunkar, K Seetharam and Cheon Kheong (ed), "*Good Practices in urban water management*" ADB, National University Singapore, 2012.
2. Marina Alberti, "*Advances in Urban Ecology*", Springer, 2008
3. Hormoz Pazwash, "*Urban storm water management*", CRC Press, 2016.


**CO-PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 1 | 2 | 1 |
| **CO2** | 2 | 1 | 2 | 1 | 2 | 1 |
| **CO3** | 3 | 1 | 3 | 3 | 2 | 2 |
| **CO4** | 3 | 2 | 2 | 2 | 2 | 2 |
| **CO5** | 2 | 2 | 3 | 3 | 3 | 3 |
| **Avg** | **2** | **1** | **2** | **2** | **2** | **2** |

• 1-low, 2-medium, 3-high

**HW3003 WATERPOWER AND DAM ENGINEERING L T P C**
**3 0 0 3**

**UNIT I HYDROELECTRIC POWER DEVELOPMENT 9**

Types of power generation – Classification – Planning and Environmental Considerations - assessment of hydropower. Components of hydropower.

**UNIT II DESIGN OF HYDROPOWER INSTALLATION 9**

Intake structure – water ғ conveyance systems – tunnels – surge tanks – penstocks pipe– control valves – anchor blocks.

**UNIT III TYPES OF POWER HOUSE 8**

Underground – semi-underground - Turbines and their foundations – Layouts - structural and geotechnical aspects of power house design.

**UNIT IV EMBANKMENT DAM ENGINEERING 9**

Nature and classification of embankment soils. Principles of design. Materials and construction. Internal seepage. Stability and stress analysis. Settlement and deformation. Rock fill embankments – cofferdam

**UNIT V CONCRETE DAM ENGINEERING 10**

Loading: Concepts and criteria. Analysis of Gravity dam, Buttress dam ~~analysis,~~ Arch dam ~~analysis~~. Design features and construction. Concrete for dams. Roller Compacted Concrete (RCC) Dams. Dam safety and instrumentation. Foundation measurements. Analysis of strain data.

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES:**

- On completion of the course, the student is expected to be able to:

**CO1** Explain the basic knowledge of planning and designing hydropower plants

**CO2** Design the components hydro power such as intake structure, water conductor systems, tunnels, surge tanks, penstocks, valves and anchor blocks.

**CO3** Describe the geotechnical aspects of power house design for underground and semi-underground structures

**CO4** Explain the design principles of rock fill and rock fill embankment dams

**CO5** Describe the concept of loading criteria and instrumentation requires for dame safety of concrete dam

**REFERENCES:**


1. Novak, P., Moffat, A.I.B., Nalluri, C. and Narayanan, R. Hydraulic Structures, eBook "Hydraulic Structures" - London , 2017, DOI: https://doi.org/10.1201/9781315274898
2. Dandekar, M.M. and Sharma, K.N. Water Power Engineering, Second Edition, Vikas Publishing House, New Delhi, 2013
3. USBR Design of Small Dams Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi 1974.
4. Sharma, H.D. Concrete Dams Metropolitan New Delhi 1981
5. Varshney, R.S. Concrete Dams Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi 1982.
6. Varshney, R.S. Hydro Power Structures – Nem Chand Bros. Roorkee 1973.
   Varshney, R.S. Hydro Power Structures – Nem Chand & Bros. 2014
7. Guthrie Brown J. (2nd Ed) Hydro-electric Engineering Practice, Blackie, 1970


**CO-PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 1 | 2 | 2 | 3 | 2 |
| **CO2** | 3 | 1 | 2 | 2 | 3 | 1 |
| **CO3** | 3 | 2 | 3 | 3 | 3 | 3 |
| **CO4** | 3 | 2 | 3 | 3 | 3 | 3 |
| **CO5** | 3 | 3 | 3 | 3 | 3 | 3 |
| **Avg** | 3 | 2 | 3 | **3** | **3** | **3** |

• 1-low, 2-medium, 3-high

**HW3004 WATER SUPPLY AND BURIED PIPELINES L T P C**
**3 0 0 3**

**UNIT I WATER SUPPLY SYSTEMS 9**

Water Demand Estimation – sources of water – types of water supply reservoir – nodal hydraulic gradient level – demand water supply consideration, Types of water supply systems - Network models – design – optimization in practice

**UNIT II HYDRAULIC PRINCIPLES AND NETWORK PARAMETERS 10**

head loss in links – HGL and TEL– pipes connected in series and parallel– analysis of water distribution network- static node, dynamic node – network performance – flow analysis - Layout – in situ lining - pipes material – appurtenances – minimization of water losses – leak detection.

**UNIT III STORM WATER DISTRIBUTION AND BURIED PIPES 9**

Planning – runoff estimation – rainfall data analysis – storm water drain design Introduction to Buried pipes – ~~external loads~~ – gravity flow design, pressurized flow- rigid and flexible pipes –pipe laying – trenchless technology

**UNIT IV RELIABILITY ASSESSMENT AND DESIGN 8**

Uncertainty and reliability –factors affecting reliable supply - assessment – reliability indices -. Design methodology - strengthening and expansion

**UNIT V FLUID TRANSIENTS 9**

Basic equations of unsteady flows through closed conduits. Method of characteristics. Transients caused by ~~centrifugal pumps and~~ hydroelectric power plants and centrifugal pumps – analysis and design of air vessels and surge tanks

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES:**

**CO1** Define the water supply and demand and water distribution network creation for the effective water supply system.

**CO2** Apply the knowledge of hydraulics in the field of pipe line system. Analyse the branch and loop network flow and head loss for various pipe material and configuration.

**CO3** Explain storm water drain buried pipeline system. Design the underground storm water drainage system with hydraulic appurtenances

**CO4** Analyse the reliability of the water supply distribution system and prepare the detailed methodology for risk management and strengthening the system.

**CO5** Apply and design the unsteady flow pipe line network in order to with stand the surge/transient developed due to power failure of centrifugal pump and also due to hydroelectric power plant.

**REFERENCES:**


1. Bhave P. R, Optimal design of water distribution networks, Narosa publishing House, New Delhi, 2003.
2. Bajwa. G. S, Practical handbook on Public Health Engineering, Deep publishers, Shimla 2003
3. Manual on water supply and treatment, CPHEEO, Ministry of Urban Development, GOI, New Delhi, 1999
4. B.A. Hauser, practical hydraulics Hand Book, Lewis Publishers, New York, 1991
5. Moser A. P, Buried pipe Design, 3rd Edition, American Water Works Association
6. Robert van Bentum and Lan K. Smout, Buried Pipe lines for surface Irrigation, The Water, Engineering and Development Centre, Intermediate Technology Publications, UK,1994
7. Wurbs R.A., and James W.P. Water Resources Engineering. Prentice Hall of India,Eastern Economic Edition. ISBN: 81-203-2151-0, NewDelhi, 2007


**CO-PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 3 | 1 | 2 | 2 | 2 | 2 |

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|---|---|---|---|---|---|---|
| **CO2** | 3 | 1 | 2 | 3 | 3 | 2 |
| **CO3** | 2 | 1 | 3 | 3 | 3 | 3 |
| **CO4** | 3 | 2 | 3 | 2 | 2 | 3 |
| **CO5** | 3 | 2 | 3 | 3 | 3 | 3 |
| **Avg** | **3** | **1** | **3** | **3** | **3** | **3** |

• 1-low, 2-medium, 3-high

**HW3005 COMPUTATIONAL INTELLIGENCE FOR HYDRO SYSTEMS L T P C**
**3 0 0 3**

**UNIT I INTERFACE MODELLING DESIGN CONCEPT 10**

Computing techniques in water resources - Design of data architectural, interface component-level ~~design~~. - Python programming - Graphical user interface - Interactive model concepts.

**UNIT II ARTIFICIAL INTELLIGENCE 10**

Heuristic search - Principle of Artificial Neural Network (ANN) - Application of ANN Model to Hydrology and Crop Water Requirement model. Fuzzy Logic concepts and Applications – Genetic Algorithms-Heuristic Optimization techniques – machine learning – deep learning

**UNIT III DIGITAL DATA MANAGEMENT 10**

Data base structure - - Data retrieval - Data format Attribute - RDBMS - Data analytics - Network data sharing - Statistical Analysis ~~(SYSTAT)~~ (SPSS) - Regression - factor analysis - histogram - scatter diagram - Goodness of fit.

**UNIT IV SIMULATION SOFTWARE IN WATER RESOURCES 8**

Surface water models (HMS) - Storm Water Management Models (SWMM) –Water Supply Network model (EPANET) – River Analysis system models (HEC-RAS)- Ground Water Flow models (MODFLOW)– Groundwater transport models – Flow 3D

**UNIT V SIMULATION MODELS IN IRRIGATION WATER MANAGEMENT 7**

Soil water assessment simulation models (SWAT) - Basin simulation models (MIKE-Hydro) Real time operation models - Water Resources Information System, Management Information System. Decision Support System

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES:**

On completion of the course, the student is expected to be able to:

**CO1** Define the concept of digital model design concept of interface and create visual programming modules

**CO2** Apply the knowledge of Artificial inelegance techniques to water resources application and optimising the resources using Fuzzy and heuristic algorithms.

**CO3** Create the data base management system and applied to statistical data analysis of participatory rural appraisal information

**CO4** Develop the simulation model for hydrological system such as surface water and groundwater modelling

**CO5** Apply the simulation model in the field of irrigation water management such as SWAT, Real time modelling and MIS

**REFERENCES:**

1. Aliev R. A, and Aliev Rashad Soft Computing and its Applications World Scientific Publications Co. Pte. Ltd. Singapore, 2001.

2. Janusz Kacprzyk Applied Decision with Soft Computing Springer, 2003
3. Carlos A. Coello Coello, David A Van Veldhuizen, Gary B Lamont, Evolutionary Algorthms for Solving Multi-objective problems, Springer, 2002.
4. Tayfur Gokmen Soft computing in water resources engineering, WIT Press, Great Britain,UK,20124.
5. John E. Gribbin, Introduction to hydraulics and hydrology with applications for Storm water Management. DELMAR, Thomson Learning, USA,2002.
6. Remson I, Hornberger G.M. and Moiz F.J., Numerical methods in Sub- Surface Hydrology. Wiley Inter Science, 1985
7. Kazda, I., Finite element Techniques in ground water flow studies (with Applications in Hydraulic and Geotechnical Engineering), Elsevier, 1990.
8. Abbott M.B, and Minns A.W. Computational hydraulics Ashgate, London,UK,2007.
9 . Loucks Daniel P., Jery R Stedinger and Douglas, A. Haith, Water Resources systems Planning and Analysis. Prentice Hall Inc., Englewood Clifts, New Jersey, 1981.

**CO-PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | 1 | 2 | 2 | 2 | 2 |
| **CO2** | 2 | 1 | 2 | 3 | 3 | 3 |
| **CO3** | 3 | 1 | 3 | 2 | 3 | 3 |
| **CO4** | 3 | 2 | 3 | 3 | 3 | 3 |
| **CO5** | 3 | 3 | 3 | 3 | 3 | 3 |
| **Avg** | **3** | **1** | **3** | **3** | **3** | **3** |

• 1-low, 2-medium, 3-high

**HW3052 LEGAL ASPECTS OF WATER RESOURCES L T P C**
**3 0 0 3**

**UNIT I HISTORICAL BACKGROUND AND CURRENT CHALLENGES 9**

Introduction – Policy, Law, Bill, Act, Rules, Notifications – Nature of Rights: Natural Rights – Customary Rights – Positive and Negative rights – Individual and Group rights -Doctrine of Riparian Rights – Doctrine of Prior Appropriation – Doctrine of Equality – Doctrine of Equitable Apportionment – Public Trust Doctrine – Doctrine of Inter-Generational Equity – Absolute Ownership Theory - Role of Law in Water Management – Conceptions of Water: Commodity, Service, Human Right – Political Ecology.

**UNIT II WATER LEGISLATION IN INDIA AND TAMILNADU 9**

Pre-Constitutional Water Laws – Constitutional Provisions: Article 14, Article 21, Directive Principles of State Policy, Fundamental Rights and Constitutional Rights, State List - Entry 17 – 73$^{rd}$ and 74$^{th}$ amendments, Article 262 – Legislative Process: Legislative, Judicial, Executive – Natural Justice – Delegation of Powers – Post-Constitutional Water Laws – National-Level Enactments - The Overview of State Acts with Case Laws: Indian Easements Act – Land-Related Legislation –Tanks – Irrigation Management – Irrigation Cess – Protection of Water Sources – Groundwater – Drinking and Domestic Water Supply – Industrial Use –Water Pollution – Climate change and Law - Torts and Crimes – Provisions of IPC relating to water (Sections 277, 430, 431, 432) - Constitutional Remedies.

**UNIT III WATER GOVERANCE: POLICIES AND LEGAL FRAMEWORKS 9**

Water Governance: Elements and dimensions of water governance - Effective water governance schemes - Indicators of good governance – Legal Framework of Water – Changing incentives through Regulation - National Water Policy – National - Level Commissions – Irrigation Management Transfer Policies and Activities – Legal Registration of WUAs – Legal Challenges in Water Allocation – Role of Local Institutions

**UNIT IV TRANSBOUNDARY WATER ISSUES 9**

International Water Law – Emerging Principles - International Law Commission – International Treaties and Protocols – Transboundary Water Issues: Indus Waters Treaty – India-Nepal Treaty – Indo-Bangladesh Cooperation – Sharing of Nile and Mekong River Basins.

**UNIT V WATER CONFLICTS IN INDIA 9**

Water conflicts - Contending Water Uses – Equity, Access and Allocation - Conflicts in Water Pricing - Water pricing practices in India and abroad - Water Quality Conflicts - Sand Mining – Macro and Micro-level Conflicts, Dams and Displacement – Quality Issues – Head-Middle-Tail conflicts – Existing cultivators Vs New cultivators - Inter-State water sharing - Tribunals - Case Studies.

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES:**

- On completion of the course, the student is expected to be able to

**CO1** Discuss the historical background of formation of laws and the types of rights.
**CO2** Explain the legal provisions existing in India and Tamil Nadu.
**CO3** Analyze the policy reforms that have taken place in water management.
**CO4** Illustrate the transboundary conflicts.
**CO5** Assess the water conflicts based on the rights issue and reveal the gaps that need to be filled up.

**REFERENCES:**


1. K.J. Joy, Suhas Paranjape, Biksham Gujja, Vinod Goudand Shruti Vispute,Water Conflicts in India – A Million Revolts in the Making.New Delhi: Routledge, 2018.
2. Gunawansa, A. & Bhullar, Lovleen. Water Governance: An Evaluation of Alternative Architectures, Gunawansa, A. & Bhullar, Lovleen, Eds.Edward Elgar Publishing, 2013.
3. Iyer R. Ramaswamy, Towards Water Wisdom: Limits, Justice, Harmony. Sage Publications, New Delhi, 2007.
4. Mollinga, Peter P., and Alex Bolding, The Politics of Irrigation Reform – Contested Policy Formulation and Implementation in Asia, Africa and Latin America. England:Ashgate Publishing Limited, 2004.
5. J. Brewer, S. Kolavalli, A. H. Kalru, G. Naik, S, Ramnarayan, K.V. Rajuand R. Sakthivadivel, Irrigation Management Transfer in India – Policies and Performance. Oxford and IBH Publishing Company, New Delhi,1999.
6. Singh, Chhatrapati, Water Rights in India, Singh, Chhatrapati,Ed.New Delhi: Indian Law Institute, 1992.


**CO-PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 2 | 2 | 2 |
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| **CO3** | 2 | 1 | 2 | 2 | 3 | 3 |
| **CO4** | 2 | 2 | 2 | 3 | 3 | 3 |
| **CO5** | 3 | 2 | 3 | 3 | 3 | 3 |
| **Avg** | **2** | **1** | **2** | **3** | **3** | **3** |

• 1-low, 2-medium, 3-high

**IW3053 CIRCULAR WATER ECONOMY L T P C**
**3 0 0 3**

**UNIT I CIRCULAR ECONOMY CONCEPTS 12**

Circular economy; Linear economy - Resource scarcity - Climatic and Non-climatic challenges to cater the linear economy - Techno-economic feasibility - Social acceptance of a circular economy Application of circular economy principles in the water sector; Resilient and inclusiveness of water systems in the circular economy; The 6 R's in the circular water economy - Circular Economy in water Conservation: Water efficiency; Reducing water wastage; Water utility-led water conservation

**UNIT II DEVELOPING THE CIRCULAR WATER ECONOMY 9**

Reuse and Recycle- Industrial water reuse and recycling; Agricultural reuse; Urban reuse; Sustainable water - management and circular economy in water-energy-food nexus

**UNIT III CIRCULAR WATER ECONOMY IN THE ENERGY SECTOR 9**

Recover-Renewable energy generation technologies at wastewater treatment facilities; Traditional renewable energy at water and wastewater treatment facilities; Resource recovery from wastewater

**UNIT IV CIRCULAR ECONOMY IN WATER RESOURCES MANAGEMENT 9**

Restore and Reclaim- Restoration of the water sources like groundwater, river water, water in lakes, artificial recharge; Managed Aquifer Recharge; Rejuvenation of water sources; Constructed Wetland (CW) technology; Repurposing the wastewater from residential buildings, industries or agriculture

**UNIT V VIRTUAL WATER 6**

Understanding virtual water and the water footprint - Water footprint categories based on consumption- Perspectives on blue water - Food production and food security - Environmental sustainability - Water pricing – Ownership - Policy implications

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES**

**CO1** Comprehend the circular economy concepts
**CO2** Demonstrate the methodology for developing water quality models in the Environment of Rivers and streams
**CO3** Demonstrate the methodology for developing water quality models in the environment of lakes, impoundments and sediments
**CO4** Illustrate the mechanism of nutrient loading, its control and heat budget for temperature models
**CO5** Comprehend the differences among the numerical modelling methods in water quality modelling and also hands-on practice for water quality analysis

**REFERENCES**


1. Delgado, A., Rodriguez, D. J., Amadei, C. A., & Makino, M., "Water in Circular Economy and Resilience (WICER)." World Bank, Washington, DC
2. Brears, R. C., "Developing the circular water economy" Springer International Publishing. 2020
3. WBCSD (World Business Council for Sustainable Development)., "Business Guide to Circular Water Management: Spotlight on Reduce, Reuse and Recycle", World Business Council for Sustainable Development. 2017
4. UNIDO (United Nations Industrial Development Organization). "Circular Economy" 2017
5. IWA. "Water Utility Pathways in a Circular Economy." IWA, London. 2016
6. Veolia., "Water at the Heart of the Circular Economy. 2014
7. McKinsey Global Institute. Resource Revolution: Meeting the World's Energy, Materials, Food, and Water Needs. McKinsey Global Institute.
8. Chittaranjan Ray, David McInnes & Matthew Sanderson (2018) Virtual water: its implications on agriculture and trade, Water International, 43:6, 717-730, DOI:10.1080/02508060.2018. 1515564
9. Allan, T., "Virtual water: Tackling the threat to our planet's most precious resource. London: I.B. Tauris & Co Ltd, 2011

**CO-PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
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| **CO1** | 1 | 2 | 2 | 3 | 2 | 3 |
| **CO2** | 1 | 3 | 3 | 3 | 3 | 3 |
| **CO3** | 2 | 3 | 3 | 3 | 2 | 3 |
| **CO4** | 2 | 2 | 2 | 3 | 3 | 3 |
| **CO5** | 3 | 3 | 2 | 3 | 3 | 3 |
| **Avg** | **2** | **3** | **2** | **3** | **3** | **3** |

• 1-low, 2-medium, 3-high

**HW3006 INTEGRATED RIVER BASIN MANAGEMENT L T P C**
**3 0 0 3**

**UNIT I BASICS OF IRBM 9**

Definition of Terminologies and Basic Concepts - Theories and Principles of IRBM - Processes/Phases in IRBM – Water scarcity issues: present and future status; Inter and Intra-basin water transfer issues – SDGs and IRBM

**UNIT II RIVER SYSTEMS AND HUMAN INTERFERENCES 9**

River Basin Fundamentals: River characteristics, flow classification, river morphology, river bends and meandering, bifurcation and confluences -Environment flow: Definition and assessment - River Functions – Human Interventions and Impacts - Mekhong Basin – River Basins in India – River Basins of Tamil Nadu – Related Case Studies

**UNIT III RIVER BASIN PLANNING AND MANAGEMENT 9**

Principles of River Basin Planning Processes - Water Allocation Principles and Policies - Operational Management, Sources of water pollution at basin scale and their management (soil erosion, river bank erosion, point and non-point sources) - Economics and Finance – Case Studies

**UNIT IV ANALYTICAL SUPPORT FOR IRBM 9**

Tools and Methods: Monitoring, Acquisition and Processing of Water Resource Data, Statistical Methods, Decision Support Systems – Computer models for IRBM – Case Studies

**UNIT V ORGANIZATIONAL AND INSTITUTIONAL FRAMEWORK 9**

Institutions - RBOs - Challenges for RBOs - Establishing effective RBOs - Key Reforms – Process of reform – Organizational analysis and stakeholder Assessment – Local Water Management Organizations - Case Studies

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES**

- On completion of the course, the student is expected to be able to:

**CO1** Describe the context and principles of IRBM.
**CO2** Understand the impacts of human interventions on the river basin management.
**CO3** Apply the principles of river basin planning and management in the context of pollution and water allocation.
**CO4** Analyse the water resources data statistically and using computerized models.
**CO5** Discuss the importance of RBOs in IRBM.

**REFERENCES:**


1. Definition-of-terminologies-and-basic- concepts of Integrated River Basin Management, http://www.universitywatersectorpartnership.org/curriculum-development/01-irbm-and sustainable-watershed-management/1-1-definition-of-terminologies-and-basic- concepts Integrated River Basin Management
2. A. Biswas, Cecilia Tortajada / Publisher: OUP India / 2013, pp: 19:24.
3. Danube River Basin Analysis 2013, http://www.icpdr.org/main/dba-2013.

4. A. Mohanakrishnan, *History of the Sathanur Reservoir Project in the Penniyaru River Basin*, 2012.
5. MosharefaShahjahan, Nick Harvey, *Integrated basin management for the Ganges: challenges and opportunities*, International Journal of River Basin Management, vol ahead- of-p, no. ahead-of-p, pp. 1-16, 2012.
6. A. Mohanakrishnan, *Water Resources Development and Management*, (Pub. No. 43), IMTI., 2004
7. Richard McNally and Sylvia Tognetti, *Tackling poverty and promoting sustainable development: Key lessons for integrated riverbasin management*, A WWF Discussion Paper,July 2002.
8. https://archive.nptel.ac.in/courses/105/106/105106145/

**CO–PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 2 | 2 | 2 |
| **CO2** | 1 | 1 | 1 | 2 | 2 | 2 |
| **CO3** | 2 | 2 | 2 | 3 | 3 | 3 |
| **CO4** | 2 | 2 | 3 | 3 | 3 | 3 |
| **CO5** | 1 | 2 | 3 | 3 | 3 | 3 |
| **Avg** | **1** | **2** | **2** | **3** | **3** | **3** |

• 1-low, 2-medium, 3-high

**HW3007 DAM HYDRAULICS AND SAFETY ENGINEERING L T P C**
**3 0 0 3**

**UNIT I HYDRAULICS OF DAM 9**

Description of dam hydraulics – design discharges of bottom outlet, spillway, intake structure and diversion tunnel or channels. Dam safety principles.

**UNIT II DIVERSION STRUCTURES 9**

Head regulators - diversion tunnel – River diversion culverts – outlet structures – cascade spillway – stilling basins.

**UNIT III OUTLETS AND INTAKE STRUCTURES 9**

Bottom outlets – hydraulics of high head gates – air entrainment and cavitation – types of intake structures.

**UNIT IV HYDRAULIC MODELING 9**

Hydraulic modelling of spillways and energy dissipators –Dimensional Analysis– dynamic flow measurements – analysis. Flow 3D model

**UNIT V DAM SAFETY 9**

Dam safety – risk and reliability – instrumentation surveillance – dam safety legislation – reservoir hazard and risk assessment. Dam break analysis - Emergency action plans.

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES**

- On completion of the course, the student is expected to be able to:

**CO1** Enumerate the different components of dam which are designed mainly on hydraulic principles
**CO2** Design the diversion structures and stilling basins
**CO3** Explain the phenomenon of air entrainment and cavitation in various structures of the dam appurtenances
**CO4** Employ the concepts of dimensional analysis and model studies to design scale models of different appurtenances of the dam
**CO5** Assess the safety of the dam through risk and reliability concepts and describe emergency action plans.

**REFERENCES:**

1. Vischer D.L., and Hager W.H. *Dam Hydraulics.* John Wiley and Sons. 1998.
2. Khatsuria, Rajnikant M. *Hydraulics of spillways and energy dissipators*. CRC Press, 2004.
3. Novak, P., Moffat, A.I.B., Nalluri, C. and Narayanan, R., 2014. *Hydraulic structures*. CRC Press.

**CO-PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 2 | 1 | 2 | 1 | 2 | 3 |
| **CO2** | 3 | 1 | 3 | 2 | 2 | 3 |
| **CO3** | 3 | 1 | 3 | 2 | 3 | 3 |
| **CO4** | 3 | 2 | 3 | 3 | 3 | 3 |
| **CO5** | 3 | 2 | 3 | 3 | 3 | 3 |
| **Avg** | **3** | **1** | **3** | **2** | **3** | **3** |

• 1-low, 2-medium, 3-high

**HW3053 RADAR METEOROLOGY L T P C**
**3 0 0 3**

**UNIT I RADAR PRINCIPLES 9**

Electromagnetic waves (EM): Electric field (EF), Magnetic field (MF), relating EF and MF, Maxwell's equations; Interaction of EM waves: refraction, reflection, scattering, absorption, Polarization of waves; Radar components: radar beam, pulse, signal processing;

**UNIT II RADAR RAY PROPAGATION, REFLECTIVITY FACTOR AND RADIAL VELOCITY 9**

Ray propagation in the idealized atmosphere: factors influencing ray paths, range and height of pulse; Radar equation: solitary target and distributed target, weather radar equation, radar reflectivity factor, the validity of Rayleigh's approximation; Radial velocity: Doppler effect, measurement, Doppler spectra

**UNIT III PRECIPITATION ESTIMATION WITH RADAR 9**

Measurement of precipitation rate, total precipitation, drop size distribution; instruments, terminal velocities, Radar reflectivity (Z) and Rainfall rate (R), Z-R relationships; Polarimetric Radar Quantitative Precipitation Estimation: Hydrometeor Classification, Polarimetric Radar-Based QPE, Microphysical Retrievals, Precipitation Typology, Precipitation Estimation

**UNIT IV ADVANCED RADAR TECHNOLOGIES FOR QUANTITATIVE PRECIPITATION ESTIMATION 9**

Mobile and Gap-Filling Radars, Spaceborne Radars: TRMM and GPM, Phased-Array Radar; Surface water radar: Stream flow radar, SAR, Altimetry; Subsurface water: L-band, c band and Ground penetrating radar

**UNIT V RADAR QPE FOR HYDROLOGIC MODELING 9**

Model Classes, Model Parameters, Model State Variables and Data Assimilation, Hydrological Model Evaluation, Hydrological Evaluation of Radar QPE; Flash Flood Forecasting: Lumped flash flood guidance and gridded flash flood guidance. Flash Flood Potential Index, threshold frequency approach

T**OTAL: 45 PERIODS**

**COURSE OUTCOMES**

On completion of the course, the student is expected to be able to

**CO1** Describe the principles of radar, its components and the interaction of waves with the atmosphere and objects

**CO2** Comprehend the radar ray propagation and the parameters that can be measured using radar waves

**CO3** Illustrate the methodology for the estimation of precipitation using radar principles

**CO4** Demonstrate the advanced techniques for precipitation estimation using mobile and space-borne radars

**CO5** Formulate and choose the appropriate model classes and parameters for hydrologic modelling using QP estimated through radar

**REFERENCES**


1. Robert M. Rauber and Stephen W. Nesbitt, “Radar Meteorology: A first course”, Wiley Blackwell, UK, 2018
2. Bringi V. N and Chandrasekar. V, “Polarimetric Doppler Weather Radar: Principles and applications”, Cambridge University Press, 2004
3. Richard J Doviak and Dusan S Zrnic, “Doppler Radar and, Weather observations”, Dover Publications Inc., New York, 2016
4. Yang Hong, Jonathan J. Gourley, “Radar Hydrology: Principles, Models, and Applications”, CRC Press, Taylor & Francis Group, USA, 2015
5. Peter Meissner, “Weather Radar: Principles and Advanced Applications”, Springer- Verlag Berlin Heidelberg Publications, 2004


**CO-PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 1 | 2 | 3 | 3 | 2 | 3 |
| **CO2** | 2 | 3 | 3 | 3 | 3 | 3 |
| **CO3** | 2 | 2 | 2 | 3 | 2 | 3 |
| **CO4** | 2 | 2 | 3 | 3 | 3 | 3 |
| **CO5** | 2 | 2 | 3 | 3 | 3 | 3 |
| **Avg** | **2** | **2** | **3** | **3** | **3** | **3** |

• 1-low, 2-medium, 3-high

**IW3054 WASTEWATER TREATMENT AND UTILIZATION L T P C**

**3 0 0 3**

**UNIT I INTRODUCTION AND BIOLOGICAL TREATMENT 9**

Types of wastewater- causes of pollution- analysis of pollutants in the waste effluents- Biological wastewater treatment- biological sludge treatment. Biological systems: Fundamentals of microbiology and biochemistry- bioenergetics and metabolism- kinetics of biological growth. Process analysis: Reaction rates- effect of temperature on reaction rate- enzyme reaction and kinetics- Reactor analysis, residence time distribution.

**UNIT II DOMESTIC WASTEWATER GENERATION AND TREATMENT PROCESS 9**

Sewerage system- Domestic wastewater characteristics- flow equalization- population equivalent- treatment flow chart- Primary, secondary and tertiary treatment of domestic wastewater- Downstream wastewater treatment for reuse and recycle- Guidelines for wastewater recycling.

**UNIT III KINETICS OF WASTEWATER TREATMENT 9**

Activated sludge process -Substrate utilization and biomass growth - estimation of kinetic parameters- Process description and its modification- performance evaluation, troubleshooting- Nitrogen removal- Biological nitrification and denitrification.

**UNIT IV ADVANCES IN WASTEWATER TREATMENT 9**

Activated sludge process design for nutrient removal-Process operation - mean cell residence time, oxygen requirement- Biological and chemical phosphorus removal- Sedimentation of activated sludge- Sequencing Batch reactor, Oxidation ditch and membrane bioreactors.

**UNIT V REUSE OF WASTEWATER 9**

Biofilm process: Trickling filter, bio tower, rotational biological contactor, integrated activated sludge and biofilm processes- Stabilization ponds and aerated lagoons- Types and their description, design, operation and maintenance- Anaerobic processes: Process description, process design, operation and maintenance, sludge digestion- Sludge treatment thickening, dewatering-mechanical and sludge drying beds- treatment of domestic wastewater- grey water management - Utilization of wastewater in agriculture and other sectors.

**TOTAL: 45 PERIODS**

**COURSE OUTCOME:**

**CO1** Understand the characteristics and composition of wastewater and the biological treatment
**CO2** Know the different types of domestic wastewater generation and its treatment
**CO3** Gain knowledge on the kinetics of wastewater treatment
**CO4** Acquire knowledge of advanced wastewater treatment technologies
**CO5** Understand the different reuses of wastewater after treatment

**REFERENCES**


1. R.l.Droste ., Theory and Practice of Water and Wastewater Treatment. John Wiley, 1997
2. Metcalf and Eddy, Wastewater Engineering. 4th Ed., McGraw Hill, 2003
3. Gray N.F, Water Technology, Elsevier India Pvt. Ltd., New Delhi, 2006.
4. B.C.Punmia., A.k. Jain, and A.K. Jain..., Environmental Engineering, Vol.II, Laxmi Publications, 2010.
5. S.R.Qasim., Wastewater Treatment Plants – Planning, Design and Operation. CRC Press, Florida, 2010.
6. K.N.Duggal ., “Elements of Environmental Engineering” S.Chand and Co. Ltd., New Delhi, 2014.
7. S.K.Garg., Environmental Engineering Vol. II, Khanna Publishers, New Delhi, 2015.


**CO – PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 1 | 2 | 3 | 3 | 3 | 2 |
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| **CO3** | 3 | 2 | 3 | 2 | 2 | - |
| **CO4** | 3 | 1 | 3 | 3 | 2 | 3 |
| **CO5** | 3 | 2 | 3 | 3 | 3 | 3 |
| **Avg** | **3** | **2** | **3** | **3** | **3** | **3** |

• 1-low, 2-medium, 3-high

**IW3055 WATER, SANITATION AND HEALTH L T P C**
**3 0 0 3**

**UNIT I FUNDAMENTALS WASH 9**

Meanings and Definition: Safe Water- Health, Nexus: Water- Sanitation - Health and Hygiene — Equity issues-Water security - Food Security. Sanitation and Hygiene (WASH) and Integrated Water Resources Management (IWRM) - Need and Importance of WASH

**UNIT II MANAGERIAL IMPLICATIONS AND IMPACT 9**

Third World Scenario — Poor and Multidimensional Deprivation--Health Burden in Developing Scenario -Factors contribute to water, sanitation and hygiene related diseases-Social: Social Stratification and Literacy Demography: Population and Migration- Fertility - Mortality- Environment: Water Borne-Water Washed and Water Based Diseases - Economic: Wage - Water and Health Budgeting -Psychological: Non-compliance - Disease Relapse - Political: Political Will.

**UNIT III CHALLENGES IN MANAGEMENT AND DEVELOPMENT 9**

Common Challenges in WASH - Bureaucracy and Users- Water Utilities -Sectoral Allocation- Infrastructure- Service Delivery: Health services: Macro and Micro- level: Community and Gender Issues- Equity Issues - Paradigm Shift: Democratization of Reforms and Initiatives.

**UNIT IV GOVERNANCE 9**

Public health -Community Health Assessment and Improvement Planning (CHA/CHIP)- Infrastructure and Investments on Water, (WASH) - Cost Benefit Analysis — Institutional Intervention-Public Private Partnership - Policy Directives - Social Insurance -Political Will vs Participatory Governance -

**UNIT V INITIATIVES 9**

Management vs Development -Accelerating Development- Development Indicators -Inclusive Development-Global and Local- Millennium Development Goal (MDG) and Targets - Five Year Plans - Implementation - Capacity Building - Case studies on WASH.

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES:**

- On completion of the course, the student is expected to be able to

**CO1** Capture fundamental concepts and terms which are to be applied and understood all throughout the study.
**CO2** Comprehend the various factors affecting water sanitation and health through the lensof third world scenario.
**CO3** Critically analyse and articulate the underlying common challenges in health care services.
**CO4** Acquire knowledge on the existing policies and its say on water sanitation and health.
**CO5** Gain an overarching insight in to the aspects of sustainability in health care.

**REFERENCES**

1. R. Bonitha Beaglehole, “R,Kjellstorm,” *Basic Epidemiology*, 2nd ed. World Health Organization, 2006.

2. N. Van Note Chism and D. J. Bickford (Improving the environment for learning: An expanded agenda, *New* Dir. Teach. Learn., pp. 91-98, 2002. doi:10.1002/tl.83Improving the Environment for learning: An Expanded Agenda.
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**CO PO MAPPING**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 1 | 2 | 3 |
| **CO2** | 1 | 1 | 1 | 2 | 2 | 3 |
| **CO3** | 1 | 2 | 2 | 2 | 3 | 3 |
| **CO4** | 1 | 1 | 2 | 2 | 3 | 3 |
| **CO5** | 2 | 3 | 3 | 3 | 3 | 3 |
| **Avg** | **1** | **2** | **2** | **2** | **3** | **3** |

• 1-low, 2-medium, 3-high

**IW3056 DROUGHT RISK ASSESSMENT AND MANAGEMENT L T P C**
**3 0 0 3**

**UNIT I UNDERSTANDING DROUGHT 10**

Hydrological Cycle – Drought Definitions based on rainfall, stream flow, vegetation and comprehensive aspects – Causes and Types of Drought – NCA classification –Characterization of Drought/water shortage/aridity/desertification - History of droughts in Worldwide and Indian context - Climate change and Drought: Rainfall variability, frequency of drought, temporal trends, heat waves, groundwater depletion and drought severity.

**UNIT II DROUGHT IMPACTS 8**

Environmental, Social and Economical impacts – Impact on Rainfed and Irrigated Agriculture - Drought effects on poverty, unemployment, and food security – Drought induced Migration - Hydropower Production - Drought effects on agribusiness and industrial sector – Case studies on Climate change induced Drought

**UNIT III DROUGHT HAZARD AND RISK ASSESSMENT 9**

Drought Hazard Assessment – Drought indices - Meteorological, Hydrological and Agricultural Drought Indices – Drought Exposure, Vulnerability and Risk Assessment – Global climate and Drought Monitoring - Early Warning and Forecasting of Drought - Application of Remote sensing and GIS in Drought Monitoring - Key Drought Indicators and Drought Declaration.

**UNIT IV DROUGHT RELIEF MEASURES 8**

Contingency Crop Planning – Support to Farmers - Relief Employment – Water Resources Management - Food Security - Tax Waiver – crop Insurance - Public aid to compensate loss of revenue - Rehabilitation/recovery programs - Cattle Camp and Fodder supply – Institutional

Response – Role of Central, State, District and Panchayat Raj Institutions – Checklist for Drought Preparedness – Drought response and recovery measures.

**UNIT V DROUGHT MITIGATION AND MANAGEMENT 9**

Drought Mitigation - Risk and Crisis Management – Water Demand Supply management - Water harvesting and Conservation – Drip and sprinkler Irrigation System – Long-term Irrigation Management – Adopting/reviewing water tariffs - Drought tolerance crop varieties - Afforestation – Drought Awareness, capacity building and Knowledge Management - Community Participation – Climate change and Adaptation - DPAP, DDP and IWMP Programmes - National Drought Policy and action plan – Climate change and Drought mitigation measures.

**TOTAL: 45 PERIODS**

**COURSE OUTCOMES:**

- On completion of the course, the student is expected to

**CO1** Classify the different types and comprehend various definitions of drought and differentiate Drought with water shortage, aridity and desertification

**CO2** Discuss the impacts of drought on various sectors.

**CO3** Evaluate the drought severity, risk and vulnerability and the modern tools of drought monitoring

**CO4** Prepare the drought plan and frame relief measures for the efficient reduction of drought risk.

**CO5** Comprehend the risk and crisis management of drought mitigation and design programs for drought risk management.

**REFERENCES:**


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**CO-PO Mapping**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 |
|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 2 | 1 | 2 |
| **CO2** | 2 | 1 | 2 | 2 | 2 | 2 |
| **CO3** | 3 | 3 | 3 | 3 | 3 | 3 |
| **CO4** | 3 | 3 | 3 | 3 | 3 | 3 |
| **CO5** | 3 | 3 | 3 | 3 | 3 | 3 |
| **Avg** | **2** | **2** | **2** | **3** | **2** | **3** |

• 1-low, 2-medium, 3-high