ENGINEERING DESIGN OF IRRIGATION SYSTEMS & WATER REQUIREMENT ASSESSMENT			
Course Code	**1MCWE201**	Scheme	2026
Type of Course	Integrated Professional Core Courses (IPCC**)**	Semester	2
Teaching Hours/Week (L:T:P)	70 (3:0:2)	CIE Marks	50
Total Hours of Pedagogy per Semester CI(L/T):LI(P):TW&SL	120(42:0:28:50)	SEE Marks	50
Credits	4	Total Marks	100
Type of Examination (IPCC):	Theory- CIE +SEE, and Lab- CIE only.	Exam Hours	03

Course outcome (Course Skill Set):

At the end of the course, the student will be able to

1. CO1 (L2): To understand techniques of irrigation and estimate the water requirement of crops
2. CO2 (L3): To evaluate the irrigation requirements of crops and to estimate the duration and frequency for irrigation
3. CO3 (L4): To design the stable canal system using different techniques
4. CO4 (L3): To analyses the stability of dam and carry out the design the gravity dam
5. CO5 (L5): To analyses and design the diversion structure

Module-1

Fundamentals of Irrigation and Water Requirement Assessment

- Irrigation development in India and major irrigation projects.
- Soil-water-plant relationship: soil texture, soil structure, soil moisture, field capacity, permanent wilting point, available water, and soil-water potential.
- Infiltration, percolation, capillary rise, evaporation, transpiration, evapotranspiration, and consumptive use.
- Irrigation efficiencies: conveyance, application, storage, distribution, use, and overall efficiency.
- Crop seasons, crop classification, base period, duty, delta, kor period, kor depth, and relationship between duty and delta.
- Crop water requirement and factors affecting water requirement.
- Effective rainfall, irrigation requirement, leaching requirement, and groundwater contribution.
- Water requirement of major crops and preparation of crop-water requirement schedules.

Linked COs: CO1, CO2 **Number of Hours: 08**

Module-2

Evapotranspiration, Irrigation Scheduling and Farm Water Management

- Reference evapotranspiration and crop evapotranspiration.
- Measurement of evapotranspiration: lysimeters, soil-water balance, evaporation pans, and field methods.
- Estimation of reference evapotranspiration using climatological and empirical methods.
- FAO Penman–Monteith method and crop coefficient approach.
- Single crop coefficient, dual crop coefficient, basal crop coefficient, and crop growth stages.
- Determination of crop coefficients for initial, development, mid-season, and late-season stages.
- Net irrigation requirement, gross irrigation requirement, and frequency of irrigation.
- Water budgeting and seasonal water allocation.

Linked COs: CO1, CO2 **Number of Hours: 09**

Module-3

Design of Irrigation Conveyance and Distribution Systems

- Planning and selection of irrigation systems based on topography, soil, climate, crop, water availability, farm size, and economic conditions.
- Design considerations for open channels and closed conduits.
- Canal alignment, canal capacity, freeboard, canal sections, hydraulic radius, wetted perimeter, and permissible velocities.
- Design of earthen, lined, and composite canals.
- Design and application of Manning's and Chezy's equations.

- Canal losses due to seepage, evaporation, vegetation, and operational practices.
- Canal lining materials, selection criteria, advantages, limitations, and construction considerations.
- Canal regulation and control structures: falls, outlets, escapes, cross-regulators, and distributaries regulators.

Linked COs: CO3 **Number of Hours: 12**

Module-4

Design of dam structures

- Types of dams and their significance
- Forces acting on gravity dam section and Derivation of Principle and shear stresses
- Modes of failures and stability analysis,
- Limiting height (High/low gravity dam)
- Elementary profile of gravity dam and Practical profile and its design as per IS code
- Design of gravity dam by gravity method
- Earthquake forces acting on gravity dam and its consideration in design and Multiple step method of design.

Linked COs: CO4 **Number of Hours: 10**

Module-5

Design of diversion structures

- Types of diversion structures
- Components of diversion structures and their importance and Causes of failure and their remedial measures
- Bligh's creep Theory for analysis of seepage
- Khosla's Theory for analysis of seepage and Method of independent variable approach
- Design of Vertical Drop Weir: including Design of floor length and thickness for weir, weir wall, cutoff depths, aprons.

Linked COs: CO5 **Number of Hours: 08**

PRACTICAL COMPONENTS OF IPCC

List of experiments

1. Determine soil texture, bulk density, porosity, moisture content, and field capacity.
2. Determine infiltration characteristics of soil using a double-ring infiltrometer or laboratory infiltrometer.
3. Determine soil-water retention characteristics and available water for selected soil samples.
4. Determine evaporation using an evaporation pan and estimate reference evapotranspiration.
5. Determine crop evapotranspiration and crop water requirement using crop coefficients.
6. Determine field application efficiency, distribution efficiency, storage efficiency, and overall irrigation efficiency.
7. Conduct a field evaluation of border, basin, or furrow irrigation using advance and recession observations.
8. Determine the discharge, pressure, application rate, and uniformity coefficient of a sprinkler system.
9. Determine emitter discharge, pressure variation, emission uniformity, and application efficiency of a drip-irrigation system.
10. Design a farm-level sprinkler or drip irrigation system using hydraulic calculations and suitable software.

Suggested Learning Resources

Textbooks

1. Michael, A. M., *Irrigation: Theory and Practice*, Vikas Publishing House.
2. Modi, P. N., *Irrigation, Water Resources and Water Power Engineering*, Standard Book House.
3. Punmia, B. C., Pande, B. B. L., and Lal, B. B., *Irrigation and Water Power Engineering*, Laxmi Publications.
4. Garg, S. K., *Irrigation Engineering and Hydraulic Structures*, Khanna Publishers.
5. Raghunath, H. M., *Irrigation Engineering*, New Age International.
6. Majumdar, D. K., *Irrigation Water Management: Principles and Practice*, Prentice Hall of India.
7. Allen, R. G., Pereira, L. S., Raes, D., and Smith, M., *Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements*, FAO.
8. Burt, C. M., Clemmens, A. J., Bliesner, R. D., Merriam, J. L., and Hardy, L. A., *Irrigation Performance Measures: Efficiency and Uniformity*, Irrigation Training and Research Center.

Reference Books and Manuals

1. FAO, *Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements*, FAO Irrigation and Drainage Paper 56.
2. FAO, *Irrigation and Drainage Paper Series*.
3. Bureau of Indian Standards, relevant standards for irrigation structures, canals, pipelines, pumps, and micro-irrigation systems.
4. Central Water Commission, manuals and guidelines on irrigation planning, hydraulic structures, and water management.
5. Central Ground Water Board, guidelines for groundwater assessment, development, and management.
6. Ministry of Jal Shakti, Government of India, guidelines on irrigation-water management and water conservation.
7. Indian Council of Agricultural Research, manuals on irrigation scheduling, crop-water management, and micro-irrigation.
8. International Commission on Irrigation and Drainage, guidelines on irrigation performance and agricultural water management.
9. National Mission on Micro Irrigation, guidelines for design, installation, operation, and maintenance of micro-irrigation systems.
10. Relevant state irrigation department manuals and standard specifications.
11. Varshney,R.S.(2002).ConcreteDams(2nded.).Oxford&IBHPublishingCo.Pvt.Ltd.
12. Creager,W.P.,Justin,J.D.,&Hinds,J.(2007).EngineeringforDams(Vols.1-3).NemChand&Brothers

Web links and Video Lectures (e-Resources)

1. FAO resources on crop evapotranspiration, irrigation scheduling, soil-water management, and water productivity.
2. Central Water Commission resources on irrigation planning and hydraulic structures.
3. Central Ground Water Board resources on groundwater and conjunctive-use management.
4. ICAR resources on crop-water requirements and micro-irrigation.
5. NPTEL and SWAYAM courses on irrigation engineering, hydrology, water resources engineering, and agricultural water management.
6. ISRO Bhuvan and satellite-based resources for watershed, crop, and irrigation mapping.
7. NASA Earthdata and related remote-sensing resources for evapotranspiration and soil-moisture assessment.
8. CROPWAT and CLIMWAT for crop-water requirement and irrigation scheduling.
9. AquaCrop for crop-water productivity and yield-response analysis.
10. EPANET, WaterGEMS, or equivalent software for pressurised irrigation-network analysis.
11. QGIS, ArcGIS, Google Earth Engine, or equivalent GIS and remote-sensing platforms.
12. Manufacturer manuals for pumps, sprinklers, emitters, filters, fertigation units, valves, sensors, and irrigation controllers.
13. Virtual laboratory demonstrations for soil-moisture, infiltration, evapotranspiration, discharge, sprinkler, and drip-irrigation experiments.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for a pass in the course.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject /course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

(i)Theory component

The CIE marks of 25 shall be earmarked for two tests.

The first test shall be conducted after completing two modules of the syllabus and the second one after completing the rest three modules.

Each test shall be conducted for 25 marks. The average of the two tests scaled down to 25 marks shall constitute the test marks for a maximum of 25 marks.

(ii) Laboratory component

Out of 25 marks, 15 marks shall be assigned for assessment of regular laboratory classwork as per the rubrics listed in Table - ICs/IPCCs1.

The remaining 10 marks shall be based on the practical test conducted by two Internal examiners appointed by the HoD. The allotment of marks shall be as per the rubrics defined for the practical test as indicated in the Table – ICs/IPCCs 1.

To qualify and become eligible to appear for the SEE of the IC/IPCC, a student shall secure at least 13 marks out of 25 in the CIE theory component, and at least 12 marks in the CIE Practical component.

Table – ICs/IPCCs 1 Distribution of marks corresponding to laboratory component

Component	Description	Marks
Allotment of marks for regular classwork		
Ability in Conducting Experiments	Initiative, skill, safety practices, teamwork, and independent handling of equipment during regular lab sessions.	5 marks
Laboratory Record / Journal	Regular and neat maintenance of lab record, accuracy of results, and timely submission.	10 marks
Subtotal		15
Allotment of marks for CIE practical test		
Laboratory Test / Experiment Performance	Ability to set up apparatus, follow procedure, take observations, and obtain correct results in the test experiment.	5 marks
Viva-Voce	Understanding of theory, concepts, and experimental procedure; ability to explain results and answer related questions.	5 marks
Subtotal		10
Total		25

Students' activities for TW/SL under NCrF:

As per National credit framework (NCrF) students must spend 120 hours of study for 4 credit courses, which include Course instructions (CI-70 hour) and Teamwork/Self learning (TW/SL-50 hours). Hence, students must complete minimum of two activities as part of NCrF. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The course coordinator can also design learning activities based on course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	TW1 – Irrigation water requirement and scheduling study: Estimate reference evapotranspiration, crop water requirement, effective rainfall, net and gross irrigation requirements, and prepare an irrigation schedule for a selected crop and command area.	25
2	TW2 – Irrigation-system design and performance audit: Prepare the layout and hydraulic design of a canal, sprinkler, drip, or farm-pipeline system; assess discharge, pressure, uniformity, efficiency, and operational deficiencies.	25
3	TW3 – Integrated command-area water-management plan: Develop a GIS-based plan incorporating water allocation, crop planning, irrigation scheduling, drainage, groundwater use, water conservation, and climate-resilience measures.	25
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	SL1 – Review of an advanced irrigation technology: Prepare a technical note on precision irrigation, sensor-based irrigation, remote-sensing-based evapotranspiration, automated drip irrigation, fertigation, or solar-powered pumping.	25
2	SL2 – Irrigation project case study: Study a major irrigation, micro-irrigation, groundwater, or drought-management project and analyse its planning approach, performance, social impacts, and sustainability.	25
3	SL3 – Regulatory and sustainability review: Compare relevant irrigation standards, groundwater regulations, water-allocation policies, wastewater-reuse requirements, energy use, drainage practices, and water-productivity indicators.	25

Sample rubrics for TW activities:

Criterion	**4 – Excellent**	**3 – Good**	**2 – Satisfactory**	**1 – Needs Improvement**
Problem understanding	The problem is clearly defined with strong justification, objectives, and scope.	The problem is mostly clear with minor gaps in framing or justification.	The problem is stated, but clarity or justification is limited.	The problem is poorly defined or unclear.
Data and method	Data collected/used is appropriate and sufficient; methods/tools are well chosen and logically applied.	Data and methods are generally appropriate with minor issues or omissions.	Data is limited or partially relevant; methods are basic or inconsistently applied.	Data is inadequate/irrelevant; methods are inappropriate or missing.
Analysis	Analysis is thorough; interpretations are logically argued and results are valid.	Analysis is generally sound with minor errors or missing details.	Analysis is partial; contains gaps or superficial interpretation.	Analysis is weak, incorrect, or largely missing.
Recommendations	Recommendations are feasible, context-specific, and clearly derived from analysis.	Recommendations are relevant but may have minor limitations or lack detail.	Recommendations are generic or only loosely connected to analysis.	Recommendations are incomplete, unrealistic, or absent.
Presentation	Work is very well organized, neat, and professionally presented, including structure, figures, and language.	Work is well organized with minor issues in formatting or clarity.	Presentation is acceptable but uneven; structure or formatting needs improvement.	Work is poorly organized, difficult to follow, or untidy.

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GROUND WATER HYDRO ENVIRONMENTAL & MODELING			
Course Code	**1MCWE202**	Scheme	2026
Type of Course	Professional Core Course	Semester	II
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	90 (42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Type of Examination (PCC):	Theory- CIE +SEE	Exam Hours	03

Course Outcome (Course Skill Set)

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

1. CO1 (L2) : Explain groundwater occurrence, aquifer properties, groundwater flow, hydro chemical characteristics, and hydro-environmental interactions.
2. CO2 (L3): Analyze groundwater quantity and quality using hydrogeological data, well-hydraulics concepts, water-quality indices, and contaminant-load estimation.
3. CO3 (L3) : Formulate conceptual and numerical groundwater-flow and solute-transport models using appropriate governing equations, boundary conditions, discretization, and input data.
4. CO4 (L4) : Apply groundwater pollution-prevention, aquifer remediation, artificial-recharge, conjunctive-use, and sustainable groundwater-management principles.
5. CO5 (L5) **:** Evaluate groundwater-management alternatives and prepare technically feasible, risk-informed, and sustainable hydro-environmental modelling proposals.

Module-1

- General Water Balance, Regional Ground Water Balance, Distribution of Subsurface Water, Different
- Types of Aquifers, Heterogeneity and Anisotropy, occurrence of Ground Water in Hydro Geological Formations, Components of Groundwater Studies.
- Structure and Types of Wells. –Problems on estimation of basic parameters.

Linked COs: CO1, CO2 **Number of Hours: 8**

Module-2

- Governing Equation of Groundwater Flow in Aquifers.
- Derivation of General Differential Equations for
- Ground Water Flow, Regional Ground Water Problems, Governing Equations for Transient Flow Conditions.

Linked COs: CO1, CO2, CO5 **Number of Hours: 9**

Module-3

- **Models for Ground Water Analysis:** Introduction, Major Applications of Groundwater Models, Numerical Modelling of Groundwater Systems, Groundwater Modelling by the Finite Difference (FD).

- **Pollution of Groundwater:** Sources of Contamination, Effect of density on migration of the contaminant solution, Importance of stratigraphic information on solute movement, Effect of disersivity on solute dispersion, Effect of distribution coefficient, Time delays and aquifer cleaning, Hydrodynamic Dispersion of Pollutants in Groundwater Environment (Advection dispersion, Molecular diffusion)

Linked COs: CO1, CO2, CO3 **Number of Hours: 9**

Module-4

- Optimization models for management of groundwater quantity and quality.
- **Well Hydraulics:** Analysis of Steady Radial Flow Towards a Well in a confined Aquifer,
- Dupuit For cheimmer (DF) Theory of free Surface Flow For Steady Flow in Unconfined Aquifers, Discharge Drawdown equation for a steady redial flow towards a well in an unconfined aquifer,
- Analysis of Steady Radial Flow in Laterally Stratified Phreatic Aquifers. Problems on well Hydraulics.

Linked COs: CO2, CO3, CO5 **Number of Hours: 8**

Module-5

- Artificial Recharge: Spreading methods, Induced-recharge method, Recharge-well method,
- Subsurface dams, Wastewater discharge, Recharge by urban storm run off, Case history.
- Geophysical Methods in Groundwater Exploration, Introduction, Electrical Resistivity Method,
- Analytical Derivation for Resistivity in Vertical Electrical Sounding, Seismic Retraction Method,
- Determination of Aquifer Thickness, Hydrogeologic well logging, Tracer techniques.

Linked COs: CO1, CO3, CO4, CO5 **Number of Hours:** 8

Suggested Learning Resources

Textbooks

1. A.K.Rastogi.,NumericalGroundwaterHydrology,PenramInternationalPublishing(India)Pvt.Ltd.2007.
2. Todd, D. K. and Mays, L. W., *Groundwater Hydrology*, Wiley.
3. Fetter, C. W., *Applied Hydrogeology*, Pearson.
4. Bear, J., *Hydraulics of Groundwater*, Dover Publications.
5. Domenico, P. A. and Schwartz, F. W., *Physical and Chemical Hydrogeology*, Wiley.
6. Anderson, M. P., Woessner, W. W. and Hunt, R. J., *Applied Groundwater Modeling: Simulation of Flow and Advective Transport*, Academic Press.

Reference Books

1. Freeze, R. A. and Cherry, J. A., *Groundwater*, Prentice Hall.
2. Kresic, N., *Hydrogeology and Groundwater Modeling*, CRC Press.
3. Bedient, P. B., Rifai, H. S. and Newell, C. J., *Ground Water Contamination: Transport and Remediation*, Prentice Hall.
4. Zheng, C. and Wang, P. P., *MT3DMS: A Modular Three-Dimensional Multispecies Transport Model*.
5. U.S. EPA, guidance documents on groundwater protection, contaminant transport, and remediation.
6. CGWB, BIS, CPCB, MoEFCC, SPCB, and relevant national guidance documents on groundwater assessment, quality, recharge, and remediation.
7. Relevant IS, WHO, and international guidance documents on groundwater quality, risk assessment, and sustainable aquifer management.

Web Links and Video Lectures (e-Resources)

1. NPTEL – Groundwater Hydrology and Groundwater Modelling.
2. Central Ground Water Board – groundwater assessment, monitoring, quality, and recharge resources.
3. U.S. Geological Survey – groundwater and groundwater-flow modelling resources.
4. U.S. EPA – groundwater protection and remediation resources.
5. MODFLOW, MODPATH, MT3DMS/SEAWAT, ModelMuse, and related documentation.
6. QGIS and open-source GIS resources for hydrogeological mapping and spatial analysis.
7. Open-source tools and spreadsheets for pumping-test analysis, water balance, uncertainty analysis, and groundwater-quality assessment.

Teaching-Learning Process (Innovative Delivery Methods)

The following strategies may be adopted to enhance the effectiveness of the teaching-learning process and facilitate achievement of course outcomes:

- Flipped classroom using groundwater datasets, modelling tutorials, and selected technical papers.
- Problem-based learning using pumping-test, groundwater-quality, recharge, and contaminant-plume datasets.

- Case-based teaching on urban groundwater, landfill leachate, mining, industrial contamination, saltwater intrusion, and managed aquifer recharge.
- Hydrogeological mapping and aquifer-characterization exercises using GIS and remote sensing.
- Spreadsheet-based water-balance, well-hydraulics, water-quality-index, and risk-assessment exercises.
- Hands-on numerical modelling using MODFLOW, MODPATH, MT3DMS/SEAWAT, ModelMuse, or equivalent platforms.
- Virtual laboratory activities for pumping-test analysis, model calibration, particle tracking, and solute transport.
- Field demonstration of groundwater-level measurement, well inventory, sampling, electrical conductivity, and aquifer testing.
- Industrial or institutional visit to a groundwater-monitoring site, recharge facility, contaminated site, or water-supply well field.
- Partial delivery by hydrogeologists, groundwater consultants, regulatory practitioners, and environmental-remediation specialists.
- Group projects involving conceptual-model preparation, calibration, scenario simulation, remediation assessment, and sustainable-management planning.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Sample rubrics for TW activities:

Criterion	**4 – Excellent**	**3 – Good**	**2 – Satisfactory**	**1 – Needs Improvement**
Problem understanding	Problem is clearly defined with strong justification and clear objectives.	Problem is mostly clear with minor gaps in framing or justification.	Problem is stated but lacks clarity or detailed justification.	Problem is poorly defined or unclear.
Data and method	Data collected/used is appropriate and sufficient; methods/tools are well chosen and logically applied.	Data and methods are generally appropriate with minor issues or omissions.	Limited or partially relevant data; methods are basic or inconsistently applied.	Data is inadequate/irrelevant; methods are inappropriate or missing.
Analysis	Analysis is thorough; interpretations are logically argued and results are valid.	Analysis is generally sound with minor errors or missing details.	Analysis is partial; contains gaps or superficial interpretation.	Analysis is weak, incorrect, or largely missing.

Criterion	4 – Excellent	3 – Good	2 – Satisfactory	1 – Needs Improvement
Recommendations	Recommendations are feasible, context-specific, and clearly derived from analysis.	Recommendations are relevant but may have minor limitations or lack detail.	Recommendations are generic or only loosely connected to analysis.	Recommendations are incomplete, unrealistic, or absent.
Presentation	Work is very well organized, neat, and professionally presented.	Work is well organized with minor issues in formatting or clarity.	Presentation is acceptable but uneven.	Work is poorly organized, difficult to follow, or untidy.

HYDROLOGICAL ANALYSIS AND WATERSHED MODELING			
Course Code	**1MCWE203**	Scheme	2026
Type of Course	Professional Core Course	Semester	II
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	90 (42:0:0:48)	SEE Marks	
Credits	3	Total Marks	50
Type of Examination (PCC):	Theory- CIE +SEE	Exam Hours	03

Course Objectives

At the end of the course, the student will be able to

1. CO1 (L2): Explain the hydrologic cycle, major hydrologic processes, and the types, sources, measurement and estimation of hydrological data used in watershed studies.
2. CO2 (L3): Analyze precipitation, abstractions, runoff and streamflow using established deterministic, empirical and statistical hydrologic techniques.
3. CO3 (L3): Develop and apply hydrologic models (unit hydrograph, rainfall–runoff, flood routing and baseflow separation) for catchment-response and design-flow estimation.
4. CO4 (L4): Delineate watersheds using GIS/remote sensing, derive morphometric and land-surface parameters, and set up watershed-scale simulation models such as SWAT/HEC-HMS.
5. CO5 (L5) : Evaluate watershed management and climate/land-use change scenarios using hydrological modelling outputs and prepare technically sound watershed management

Module-1

Fundamentals of Hydrology and Hydrologic Data

- Hydrologic Cycle: Components, systems approach, spatial and temporal scales, surface and subsurface processes, and the role of hydrology in water-resources and watershed management.
- Precipitation: Forms and measurement using rain gauges, radar, and satellite products; data consistency; intensity–duration–frequency (IDF) analysis; depth–area relationships; and areal precipitation estimation.
- Hydrologic Data Types and Sources: Rainfall, streamflow, groundwater, soil, and land-use data; national and international data repositories.

Linked COs: CO1 **Number of Hours:** 8

Module-2

Runoff Processes, Streamflow Analysis and Unit Hydrograph

- Watershed Response and Runoff Generation: Hortonian and saturation-excess runoff, subsurface and baseflow contributions, and catchment characteristics influencing runoff.
- Streamflow Measurement and Analysis: Stage–discharge relationships, hydrographs, baseflow separation methods, flow-duration curves, and low-flow/high-flow indices.
- Unit Hydrograph Theory: Assumptions, derivation from observed data, S-curve and convolution methods, synthetic unit hydrographs, and design storm concepts.

Linked COs: CO2, CO3 **Number of Hours:** 9

Module-3

Flood Hydrology, Frequency Analysis and Routing

- Flood Hydrology: Design flood concepts, peak-flow estimation for small and large catchments, regional flood equations, and index-flood methods.
- Frequency Analysis of Hydrologic Extremes: Basic idea on probability distributions for floods and rainfall, plotting-position formulas, return period, risk, and reliability for design.
- Flood Routing: Hydrologic and hydraulic routing; reservoir routing using the storage–indication method; channel routing using the Muskingum method and its variants; model selection and stability

considerations.

Linked COs: CO2, CO3 **Number of Hours:** 9

Module-4

Watershed Delineation, GIS-Based Hydrologic Modelling

- Watershed delineation: use of DEM, flow-direction and flow-accumulation algorithms; stream-network extraction and sub-basin definition in GIS environment.
- Morphometric analysis: area, perimeter, slope, relief, shape indices, drainage density, stream-order statistics and hypsometric analysis for watershed characterization.
- Spatial data for modelling: soil maps, land-use/land-cover, climate inputs, hydro-meteorological stations; data preprocessing, database development and parameterization.
- Introduction to watershed models: structure and capabilities of SWAT, HEC-HMS, MIKE SHE (or similar); model setup, schematization, input preparation, calibration, validation and uncertainty appraisal.

Linked COs: CO3, CO4 **Number of Hours:** 8

Module-5

Watershed Management, Scenario Analysis and Case Studies

- Watershed Management Objectives: Water availability, flood mitigation, soil and water conservation, groundwater recharge, and environmental protection; best-management practices (BMPs) at plot, field, and catchment scales.
- Scenario Analysis: Land-use and land-cover change, climate-change impacts on rainfall and temperature, reservoir construction and operation scenarios, and green infrastructure for urban stormwater management.
- Integrated Watershed Management Planning: Prioritization of sub-watersheds, intervention packages, performance indicators, SDG alignment, and multi-criteria evaluation.

Linked COs: CO4, CO5 **Number of Hours:** 8

Suggested Learning Resources (Text Book/ Reference Book/ Manuals)

Text books

1. Chow, V. T., Maidment, D. R. and Mays, L. W., Applied Hydrology, McGraw–Hill.
2. Subramanya, K., Engineering Hydrology, Tata McGraw–Hill.
3. Raghunath, H. M., Hydrology – Principles, Analysis and Design, New Age International.
4. Singh, V. P., Computer Models of Watershed Hydrology (selected chapters).
5. Vijay P. Singh and Donald K. Frevert (eds.), Watershed Models, CRC Pres

Reference books / Manuals

1. Bedient, P. B., Huber, W. C. and Vieux, B. E., Hydrology and Floodplain Analysis, Pearson.
2. ASCE Manuals and Reports on Engineering Practice related to hydrologic modelling and watershed management.
3. User manuals and technical reports for SWAT, HEC-HMS and other relevant watershed modelling tools.
4. National and state agency guidelines (CWC, IMD, NIH, MoJS) on hydrologic data, design floods and watershed development (latest editions).
5. Relevant BIS standards on hydrometeorological observations, flood estimation and watershed management.

Web links and Video Lectures (e-Resources)

1. NPTEL – Hydrology and Water Resources Engineering, Advanced Hydrology, Watershed Management courses.
2. NIH, CWC and IMD portals for hydrologic data, flood reports and manuals.
3. USGS, USDA and international portals for DEM, land-use and soil data (e.g., HydroSHEDS, NRCS SSURGO).
4. Online documentation and tutorials for SWAT, HEC-HMS and QGIS-based watershed delineation.
5. Open-source tools and spreadsheets for hydrologic analysis, frequency analysis, watershed modelling and scenario evaluation.

Teaching–Learning Process (Innovative Delivery Methods)

The following strategies may be adopted to enhance the effectiveness of the teaching–learning process and facilitate achievement of course outcomes, following the spirit of the enclosed PCC template.

- Flipped classroom sessions on core hydrologic concepts and model components with pre-class readings and videos.
- Problem-based learning using real rainfall–runoff and streamflow datasets from Indian watersheds and urban catchments.
- Case-based teaching on rural, agricultural, forested and urban watersheds, highlighting contrasting hydrologic behaviour and management needs.
- GIS and modelling laboratory sessions using QGIS and selected tools (SWAT, HEC-HMS or equivalent) for watershed delineation and simulation.
- Group mini-projects involving hydrological analysis, model setup, calibration and scenario evaluation for a chosen watershed, culminating in a technical report.
- Field visit or virtual field tour to a gauged watershed, hydro meteorological observatory or watershed-development project to observe instruments and interventions.
- ICT-enabled teaching using dashboards, online data portals, model GUIs and collaborative platforms for data sharing and reporting.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per the National Credit Framework, students must spend 90 hours of study for a 3-credit course, including Course Instructions (CI – 42 hours) and Teamwork/Self-learning (TW/SL – 48 hours). Hence, students must complete a minimum of two activities as part of NCrF. These learning activities shall be considered CCA components of CIE and evaluated using rubrics developed for each activity.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	TW1: Hydrological data compilation and preliminary analysis for a selected watershed – Collect rainfall, streamflow, soil and land-use data for a chosen basin; perform data quality checks, basic statistical analysis, intensity–duration–frequency (IDF) or depth–area–duration (DAD) analysis, and prepare a technical note on hydrologic characteristics and data gaps.	24
2	TW2: Rainfall–runoff modelling and flood estimation for a catchment – Delineate the watershed using DEM in GIS, derive morphometric parameters, set up a lumped or semi-distributed rainfall–runoff model (e.g., unit hydrograph / HEC-HMS / SWAT), calibrate using observed data, estimate design flood for a specified return period, and submit a concise modelling report with assumptions, results and limitations.	24

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	SL1: Study national and international guidelines on flood estimation and watershed management (e.g., CWC/NIH manuals, FEMA/USACE documents); prepare a comparative note on methods, applicability to Indian conditions and relevance to course outcomes.	24
2	SL2: Review a published case study on watershed modelling (e.g., SWAT/HEC-HMS application in an Indian or global basin); evaluate model setup, calibration/validation approach, key findings and implications for water resources planning, and submit a critical review note.	24
3	SL3: Complete an NPTEL or equivalent online module on hydrology, flood hydrology, or watershed modelling; prepare a reflective technical note linking the learned concepts to course modules, COs and potential project work.	24

Sample rubrics for TW activities:

Criterion	4 – Excellent	3 – Good	2 – Satisfactory	1 – Needs Improvement
Problem understanding	Problem is clearly defined with strong justification and clear objectives.	Problem is mostly clear with minor gaps in framing or justification.	Problem is stated but lacks clarity or detailed justification.	Problem is poorly defined or unclear.
Data and method	Data collected/used is appropriate and sufficient; methods/tools are well chosen and logically applied.	Data and methods are generally appropriate with minor issues or omissions.	Limited or partially relevant data; methods are basic or inconsistently applied.	Data is inadequate/irrelevant; methods are inappropriate or missing.
Analysis	Analysis is thorough; interpretations are logically argued and results are valid.	Analysis is generally sound with minor errors or missing details.	Analysis is partial; contains gaps or superficial interpretation.	Analysis is weak, incorrect, or largely missing.
Recommendations	Recommendations are feasible, context-specific, and clearly derived from analysis.	Recommendations are relevant but may have minor limitations or lack detail.	Recommendations are generic or only loosely connected to analysis.	Recommendations are incomplete, unrealistic, or absent.
Presentation	Work is very well organized, neat, and professionally presented.	Work is well organized with minor issues in formatting or clarity.	Presentation is acceptable but uneven.	Work is poorly organized, difficult to follow, or untidy.

WATER POLLUTION SOLUTIONS AND CONTROL TECHNOLOGIES			
Course Code	1MCWE204	Scheme	2026
Type of Course	Professional Core Course	Semester	II
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per Semester CI (L /T): LI(P):TW&SL	90 (42:0:0:48)	SEE Marks	
Credits	3	Total Marks	50
Type of Examination (PCC):	Theory- CIE +SEE	Exam Hours	03

Course Objectives

At the end of the course, the student will be able to

1. CO1 (L2): Explain the sources, characteristics, transport, fate, and effects of physical, chemical, biological, and emerging pollutants in water and wastewater.
2. CO2 (L2): Analyze water and wastewater quality using relevant physical, chemical, biological, and microbiological parameters and standard methods.
3. CO3: (L3) Select and justify suitable physical, chemical, biological, and advanced treatment processes for municipal and industrial wastewater.
4. CO4 (L3) : Apply process design concepts, mass balances, reaction kinetics, and performance assessment methods to water-pollution-control systems.
5. CO5 (L4) : Evaluate solutions for nutrient removal, sludge management, resource recovery, reuse, and pollution prevention using sustainability and life-cycle perspectives.
6. CO6 (L5) : Assess compliance, monitoring, risk management, and digital control strategies for water-quality protection and wastewater-treatment facilities.

Module-1

Water Pollution Fundamentals, Sources and Quality Assessment:

- Introduction to water pollution: concepts, sources, pathways, receiving-water systems, assimilative capacity, pollution loads, point and non-point sources, and watershed-based pollution management. Physical, chemical, biological, radiological, and emerging contaminants: nutrients, pathogens, heavy metals, pesticides, pharmaceuticals, personal-care products, microplastics, and PFAS. Effects of pollution on public health, aquatic ecosystems, eutrophication, biomagnification, and water security.
- Water-quality criteria, designated best uses, environmental indicators, water-quality index, sampling design, preservation, chain of custody, quality assurance and quality control. Characterization of domestic and industrial wastewater: flow variation, pH, temperature, solids, turbidity, electrical conductivity, alkalinity, hardness, DO, BOD, COD, TOC, nutrients, oil and grease, toxicity, and microbial indicators. Pollution prevention, cleaner production, source reduction, segregation, and water auditing.

Linked COs: CO1, CO2, CO6. **Number of Hours: 09**

Module-2

Preliminary, Physical and Chemical Treatment Technologies:

- Treatment objectives and process selection. Screening, comminution, grit removal, oil and grease removal, flow measurement, equalization, neutralization, and preliminary treatment. Theory and applications of sedimentation: discrete, flocculent, zone, and compression settling; settling-tank performance and design considerations.
- Coagulation and flocculation: colloidal stability, zeta potential, coagulants, polymers, rapid mixing, slow mixing, jar testing, and chemical precipitation. Dissolved-air flotation, centrifugation, filtration, granular-media filters, pressure filters, membrane pretreatment, and adsorption using activated carbon and other sorbents.
- Ion exchange, electrocoagulation, chemical oxidation, and control of colour, odour, and volatile pollutants. Residuals generated by physical and chemical treatment.

Linked COs: CO2, CO3, CO4. **Number of Hours: 08**

Module-3

Biological Wastewater Treatment and Nutrient Removal:

- Fundamentals of biological treatment: microbial growth, substrate utilization, electron acceptors, biodegradability, loading rates, growth kinetics, decay, oxygen demand, and process stoichiometry. Suspended-growth systems: conventional activated sludge, completely mixed and plug-flow reactors, extended aeration, oxidation ditches, sequencing batch reactors, membrane bioreactors, and biological nutrient removal.
- Attached-growth systems: trickling filters, rotating biological contactors, bio-towers, moving-bed biofilm reactors, and integrated fixed-film activated sludge. Anaerobic treatment: principles, stages of anaerobic digestion, methane production, UASB reactors, anaerobic filters, and anaerobic ponds.
- Nutrient removal: nitrification, denitrification, shortcut nitrogen removal, biological phosphorus removal, chemical phosphorus precipitation, and process control. Stabilization ponds, constructed wetlands, decentralized treatment, and nature-based solutions.

Linked COs: CO1, CO3, CO4, CO5. **Number of Hours: 09**

Module-4

Advanced Treatment, Disinfection and Water Reclamation:

- Need for tertiary and advanced treatment; treatment-train development for reuse and sensitive receiving waters. Membrane processes: microfiltration, ultrafiltration, nanofiltration, reverse osmosis, membrane distillation, electrodialysis, membrane fouling, concentration management, and cleaning.
- Advanced oxidation processes: ozone, UV/H_2O_2, Fenton and photo-Fenton processes, photocatalysis, electrochemical oxidation, sonochemical processes, and removal of recalcitrant contaminants. Adsorption, ion exchange, selective media, activated carbon, and hybrid processes.
- Disinfection principles and kinetics: chlorination, chlorine dioxide, chloramines, ozone, ultraviolet radiation, and combined systems; disinfection by-products and residual management.
- Water reclamation, fit-for-purpose treatment, potable and non-potable reuse, decentralised reuse systems, and risk-based water-safety planning. Digital sensors, online monitoring, SCADA, process automation, artificial intelligence, and predictive control for treatment plants.

Linked COs: CO2, CO3, CO4, CO6. **Number of Hours: 08**

Module-5

Sludge, Resource Recovery, Compliance and Sustainable Control:

- Sludge characteristics, thickening, stabilization, conditioning, dewatering, drying, composting, thermal treatment, co-digestion, disposal, and beneficial use. Odour, greenhouse-gas, aerosol, and corrosion control in treatment plants.
- Resource recovery: biogas, energy, nutrients, struvite, cellulose, water recovery, and circular-economy approaches. Industrial wastewater treatment: source-specific pollutants and treatment trains for textile, tannery, pharmaceutical, food-processing, dairy, pulp and paper, electroplating, mining, and petrochemical industries; common effluent treatment plants and zero-liquid-discharge concepts.
- Environmental compliance, consent and monitoring requirements, effluent standards, receiving-water assessment, environmental audit, occupational health and safety, emergency response, and treatment-plant reliability. Life-cycle assessment, energy and carbon footprint, climate-resilient treatment, decentralized systems, and case studies of river-restoration and wastewater-reuse projects.

Linked COs: CO3, CO5, CO6. **Number of Hours: 08**

Suggested Learning Resources

Textbooks

1. Metcalf & Eddy/AECOM, *Wastewater Engineering: Treatment and Resource Recovery*, McGraw Hill.
2. C. S. Rao, *Environmental Pollution Control Engineering*, New Age International.
3. S. K. Garg, *Sewage Disposal and Air Pollution Engineering*, Khanna Publishers.
4. M. N. Rao and A. K. Datta, *Wastewater Treatment: Rational Methods of Design and Industrial Practices*, Oxford and IBH.
5. R. S. Ramalho, *Introduction to Wastewater Treatment Processes*, Academic Press.

Reference Books

1. Tchobanoglous, Stensel, Tsuchihashi and Burton, *Wastewater Engineering: Treatment and Resource Recovery*, McGraw Hill.
2. W. Wesley Eckenfelder, *Industrial Water Pollution Control*, McGraw Hill.
3. Mark J. Hammer and Mark J. Hammer Jr., *Water and Wastewater Technology*, Pearson.
4. Qasim, S. R., *Wastewater Treatment Plants: Planning, Design and Operation*, CRC Press.
5. AWWA, *Water Quality and Treatment*, McGraw Hill.
6. Relevant BIS standards, CPCB guidelines, Environment (Protection) Rules, Water Act provisions, and sector-specific effluent standards.

Web links and Video Lectures (e-Resources)

1. NPTEL/SWAYAM courses on environmental engineering, wastewater treatment, water-quality modelling, and industrial pollution control.
2. CPCB resources on water-quality standards, sewage-treatment plants, effluent standards, monitoring, and river-water quality.
3. WHO Guidelines for Drinking-water Quality and resources on water safety, wastewater reuse, and public-health risk management.
4. US EPA technical resources on wastewater treatment, nutrient removal, water reuse, and emerging contaminants.
5. Open-source demonstrations and tutorials on BioWin, GPS-X, WEST, EPANET, SWMM, QGIS, Python, and spreadsheet-based treatment-process calculations.

Teaching-Learning Process (Innovative Delivery Methods)

The following strategies may be adopted to enhance the effectiveness of the teaching-learning process and facilitate achievement of course outcomes:

- Flipped classroom using short lectures, process animations, and guided reading.
- Problem-based learning on treatment-process selection, plant troubleshooting, and compliance improvement.
- Case-based teaching using municipal, industrial, lake-restoration, and water-reuse projects.
- Laboratory or virtual demonstrations for jar testing, settling, BOD/COD analysis, respirometry, filtration, adsorption, and disinfection.
- Process-design studio using spreadsheets, open-source software, online calculators, and simplified digital twins.
- Industrial visits to sewage-treatment plants, common effluent-treatment plants, water-reclamation facilities, and laboratories.
- Guest lectures from pollution-control authorities, utilities, consultants, and treatment-technology providers.
- ICT-enabled teaching with GIS-based watershed assessment, dashboards, SCADA examples, and sensor data.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per the National Credit Framework, students must spend 90 hours of study for a 3-credit course, including Course Instructions (CI – 42 hours) and Teamwork/Self-learning (TW/SL – 48 hours). Hence, students must complete a minimum of two activities as part of NCrF. These learning activities shall be considered CCA components of CIE and evaluated using rubrics developed for each activity.

Sl. No.	Term Work Activity	Number of Hours / Semester
1	**TW1 – Wastewater Characterization and Treatment-Train Selection:** Characterize a supplied municipal or industrial wastewater dataset, identify key pollutants, prepare a process-flow diagram, and justify the selected treatment units. Linked COs: CO1, CO2, CO3, CO6.	24
2	**TW2 – Treatment Process Design and Performance Assessment:** Carry out design calculations for selected units such as equalization, sedimentation, activated sludge, SBR, MBBR, anaerobic reactor, filtration, disinfection, or membrane treatment, and evaluate expected performance. Linked COs: CO2, CO3, CO4.	24
3	**TW3 – Water Reuse and Pollution-Control Case Study:** Study a wastewater-reuse, river-restoration, industrial effluent, or resource-recovery project and present treatment performance, compliance, sustainability, and risk-management findings. Linked COs: CO5, CO6.	24
Sl. No.	**Self-Learning Activity**	**Number of Hours / Semester**
1	SL1 – Advanced Treatment Technology Review: Prepare a technical review of membrane processes, adsorption, advanced oxidation, electrochemical treatment, or emerging-contaminant removal, including advantages, limitations, energy requirements, and applications. Linked COs: CO3, CO5.	**24**
2	SL2 – Digital Water-Quality and Compliance Review: Use a public dataset or published case study to prepare a water-quality assessment, pollution-load analysis, GIS map, dashboard, or process-monitoring review. Linked COs: CO2, CO5, CO6.	**24**

Sample rubrics for TW activities:

Criterion	4 – Excellent	3 – Good	2 – Satisfactory	1 – Needs Improvement
Problem understanding	Problem is clearly defined with strong justification and clear objectives.	Problem is mostly clear with minor gaps in framing or justification.	Problem is stated but lacks clarity or detailed justification.	Problem is poorly defined or unclear.
Data and method	Data collected/used is appropriate and sufficient; methods/tools are well chosen and logically applied.	Data and methods are generally appropriate with minor issues or omissions.	Limited or partially relevant data; methods are basic or inconsistently applied.	Data is inadequate/irrelevant; methods are inappropriate or missing.
Analysis	Analysis is thorough; interpretations are logically argued and results are valid.	Analysis is generally sound with minor errors or missing details.	Analysis is partial; contains gaps or superficial interpretation.	Analysis is weak, incorrect, or largely missing.
Recommendations	Recommendations are feasible, context-specific, and clearly derived from analysis.	Recommendations are relevant but may have minor limitations or lack detail.	Recommendations are generic or only loosely connected to analysis.	Recommendations are incomplete, unrealistic, or absent.
Presentation	Work is very well organized, neat, and professionally presented.	Work is well organized with minor issues in formatting or clarity.	Presentation is acceptable but uneven.	Work is poorly organized, difficult to follow, or untidy.

OPEN CHANNEL HYDRAULICS			
Course Code	**1MCWE205A**	Scheme	2026
Type of Course	Professional Elective Course	Semester	II
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per Semester CI(L/T):LI(P):TW&SL	90(42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Type of Examination (PEC):	Theory- CIE +SEE	Exam Hours	03

Course outcome (Course Skill Set):

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

1. CO1, (L2): Explain the fundamentals of open channel flow, including classification of flows, velocity and pressure distribution, and the energy and momentum principles.
2. CO2, (L2): Analyze uniform flow using resistance equations and design hydraulically efficient lined and unlined (erodible) channels.
3. CO3, (L3): Apply specific energy and specific force concepts to critical flow computations, channel transitions, and flow measuring structures.
4. CO4, (L3): Compute and classify gradually varied and spatially varied flow profiles in prismatic and non-prismatic channels using analytical and numerical methods.
5. CO5, (L4): Evaluate rapidly varied flow phenomena such as hydraulic jumps, flow over spillways and under gates for the design of energy dissipation structures.
6. CO6, (L5) : Analyze unsteady flow, surges and flood routing in open channels using Saint-Venant equations and computational tools such as HEC-RAS.

Module-1

Uniform Flow and Channel Design:

Types of channels, classification of flows, geometric elements of channel sections, velocity distribution, velocity coefficients (α and β), and pressure distribution in straight and curvilinear flows. Uniform flow: Chezy and Manning equations, factors affecting and estimation of Manning's n, conveyance, section factor for uniform flow, and computation of normal depth. Hydraulically efficient channel sections, compound channels and composite roughness. Design of non-erodible (lined) and erodible (unlined) channels by permissible velocity and tractive force methods.

Linked COs: CO1, CO2. **Number of Hours: 08**

Module-2

Energy and Momentum Principles and Critical Flow:

Specific energy and specific energy diagram, critical depth, section factor for critical flow, and computation of critical depth in rectangular, triangular, trapezoidal and circular channels. Specific force and the momentum principle. Channel transitions with change in bed elevation and width, choking of flow, and design of subcritical transitions. Flow measurement: broad-crested weir, critical-depth (venturi and Parshall) flumes, and free overall (end depth) method.

Linked COs: CO1, CO3. **Number of Hours: 09**

Module-3

Gradually Varied Flow:

- Dynamic equation of gradually varied flow (GVF), assumptions, classification and characteristics of flow profiles, and control sections. Computation of GVF profiles by direct integration (Bresse and Chow methods using varied flow function), graphical integration, direct step and standard step methods. Flow profiles in non-prismatic channels and in channels with changes in slope. Spatially varied flow with increasing and decreasing discharge: side-channel spillways, side weirs and bottom racks. Spreadsheet and computer-based profile computation.

Linked COs: CO2, CO4. **Number of Hours: 09**

Module-4

Rapidly Varied Flow and Energy Dissipation:

- Hydraulic jump in horizontal rectangular channels: sequent depths, energy loss, efficiency, length and types of jumps. Jumps in sloping and non-rectangular channels, location of hydraulic jump, and hydraulic jump as an energy dissipater. Stilling basins: USBR types and design as per relevant IS codes. Flow over spillways: ogee spillway crest profile and discharge coefficient; flow under sluice gates. Flow in channel bends and super elevation.

Linked COs: CO3, CO5. **Number of Hours: 08**

Module-5

Unsteady Flow and Flood Routing

- Gradually varied unsteady flow: Saint-Venant equations of continuity and momentum, method of characteristics, and explicit and implicit (Preissmann) finite difference schemes. Rapidly varied unsteady flow: positive and negative surges and the dam-break problem. Flood routing: hydrologic (Muskingum) and hydraulic routing, kinematic and diffusion wave approximations. Introduction to HEC-RAS for one-dimensional steady and unsteady flow modelling of river reaches.

Linked COs: CO4, CO6. **Number of Hours: 08**

Suggested Learning Resources:

Textbooks:

1. Chow, V. T., *Open-Channel Hydraulics*, McGraw-Hill (Reprint), Blackburn Press.
2. Subramanya, K., *Flow in Open Channels*, 5th Edition, McGraw Hill Education.
3. Chaudhry, M. H., *Open-Channel Flow*, 2nd Edition, Springer.
4. Srivastava, R., *Flow Through Open Channels*, Oxford University Press.

Reference Books:

1. Henderson, F. M., *Open Channel Flow*, Macmillan Publishing Co.
2. French, R. H., *Open-Channel Hydraulics*, McGraw-Hill.
3. Sturm, T. W., *Open Channel Hydraulics*, 2nd Edition, McGraw-Hill Education.
4. Chanson, H., *The Hydraulics of Open Channel Flow: An Introduction*, 2nd Edition, Butterworth-Heinemann (Elsevier).

Web links and Video Lectures(e-Resources):

1. NPTEL/SWAYAM courses on open channel flow, hydraulic engineering and river hydraulics.
2. US Army Corps of Engineers, HEC-RAS User's Manual and Hydraulic Reference Manual (hec.usace.army.mil).
3. Virtual Labs (vlab.co.in): Fluid mechanics and hydraulics experiments on open channel flow.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Laboratory Demonstrations on Tilting Flume

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	**TW-1: Uniform Flow and Channel Design Worksheet** Students shall develop a spreadsheet/Python tool to compute normal and critical depths for rectangular, trapezoidal and circular sections, and use it to design a lined and an unlined canal for a given discharge, comparing the results with hydraulically efficient sections.	24
2	**TW-2: Gradually Varied Flow Profile Computation** Students shall compute and classify the water surface profile upstream of a control structure using the direct step and standard step methods, plot the profile, and compare the results with an HEC-RAS steady flow simulation.	24
3	**TW-3: Hydraulic Jump and Stilling Basin Design** Students shall design a stilling basin for given spillway data, including sequent depth, jump length, tail water rating check and basin appurtenances as per relevant IS codes, and present the design with neat sketches.	24
4	**TW-4: Laboratory Flume Study Report** Students shall conduct/analyse tilting flume experiments to determine Manning's n, the specific energy curve and hydraulic jump characteristics, and compare the measured values with theoretical predictions.	24

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	**SL-1: Case Study on River Flooding:** Students shall study a recent flood event in an Indian river basin and present the hydraulic causes, channel capacity issues, backwater effects and flood mitigation measures adopted.	24
2	**SL-2: MOOC on Open Channel Flow** Students shall complete selected NPTEL/SWAYAM modules on open channel flow and submit a summary report with solved problems on the topics covered.	24

3	**SL-3: HEC-RAS River Reach Modelling:** Students shall build a one-dimensional steady flow model of a river reach using available cross-section data, estimate flood levels for design discharges and interpret the results.	24
4	**SL-4: Review of Spillway and Energy Dissipater Failures:** Students shall review a documented spillway or stilling basin failure (e.g., Oroville Dam spillway, 2017), identify the hydraulic causes and present the lessons for design and maintenance.	24

Sample rubrics for TW activities:

Criteria	**Excellent (4)**	**Good (3)**	**Satisfactory (2)**	**Needs Improvement (1)**
Understanding of hydraulic concepts	Correctly applies energy, momentum and resistance principles with clear justification of assumptions.	Applies most principles with minor omissions.	Basic grasp; explanation is partial.	Incomplete or incorrect application of principles.
Computational accuracy	Accurate computations, correct profile classification and design values.	Minor errors in computation or interpretation.	Several errors in computation or concepts.	Major errors in computation.
Documentation quality	Professional format with clear sketches, tables and profile plots.	Mostly well formatted and complete.	Adequate but lacking clarity or consistency.	Poorly organized or incomplete.
Practical application	Strong linkage to field practice, relevant IS codes and design tools.	Good linkage with limited depth.	Basic application only.	No meaningful practical linkage.

URBAN FLOOD MODELLING AND MANAGEMENT			
Course Code	**1MCWE205B**	Scheme	2026
Type of Course	**Professional Elective Course**	Semester	II
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per Semester CI (L/T):LI(P):TW&SL	90(42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Type of Examination (PCC):	Theory- CIE +SEE	Exam Hours	03

Course outcome (Course Skillset):

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

1. CO1 (L2) Explain the causes, types, characteristics and impacts of urban flooding and the hydrological processes governing urban catchments.
2. CO2 (L2): Estimate design rainfall and urban runoff using IDF relationships, design storms and suitable rainfall–runoff methods.
3. CO3 (L3): Analyze and design urban storm water drainage systems using hydraulic principles and relevant codal provisions.
4. CO4 (L4): Apply hydrological, 1D/2D hydrodynamic and GIS-based models (EPA SWMM, HEC-HMS, HEC-RAS) to simulate urban flood inundation.
5. CO5 (L4) : Evaluate urban flood hazard, vulnerability and risk, and propose structural, non-structural and SUDS/LID mitigation measures.
6. CO6 (L5) : Develop integrated urban flood management strategies incorporating early warning, climate change adaptation and policy frameworks.

Module-1

Urban Hydrology and Urban Flooding:

- Urbanisation and the hydrological cycle: effects of imperviousness on infiltration, runoff volume, peak discharge and time to peak.
- Urban flooding: definition, types (pluvial, fluvial, coastal, flash floods, drainage congestion) and causes.
- Characteristics of urban floods versus rural floods; social, economic, environmental and public health impacts.
- Case studies of urban floods in India: Mumbai (2005), Chennai (2015), Hyderabad (2020) and Bengaluru (2022).
- Urban hydrological data: rain gauges, automatic weather stations, weather radar, satellite rainfall products and flow gauging.
- Urban catchment delineation, land use/land cover and imperviousness estimation using remote sensing and GIS.

Linked COs: CO1, CO2 **Number of Hours: 08**

Module-2

Urban Rainfall and Runoff Estimation:

- Rainfall analysis: frequency analysis, return period, Intensity-Duration-Frequency (IDF) curves and depth-area-duration relationships.
- Design storms: alternating block method, SCS and Huff distributions, Chicago hyetograph and short-duration rainfall disaggregation.
- Abstractions: interception, depression storage and infiltration models (Horton, Green-Ampt, SCS-CN).
- Peak runoff estimation: Rational method and its modifications, time of concentration formulae.
- Runoff hydrographs: unit hydrograph, SCS synthetic unit hydrograph, time-area and non-linear reservoir methods for urban catchments.
- Impact of climate change on rainfall extremes: non-stationary IDF curves and downscaling concepts.

Linked COs: CO1, CO2 **Number of Hours: 09**

Module-3

Urban Storm water Drainage Systems:

- Components of urban drainage: inlets, gutters, manholes, sewers, open drains, culverts and outfalls; separate and

combined systems.

- Hydraulics of drains: uniform flow (Manning's equation), gradually varied flow, surcharge and pressurised flow in sewers.
- Design of storm water drains as per the CPHEEO Manual on Storm Water Drainage Systems: design criteria, return periods and limiting velocities.
- Flow routing in drainage networks: kinematic wave and dynamic wave (Saint-Venant equations) approaches.
- Detention and retention basins: sizing and storage-indication routing; pumping stations and tidal/backwater-affected outfalls.
- Operation and maintenance of drainage systems: silting, encroachments, solid waste blockage and desilting practices.

Linked COs: CO2, CO3Number of Hours: 08

Module-4

Urban Flood Modelling:

- Classification of flood models: hydrological and hydraulic, lumped and distributed, 1D, 2D and coupled 1D–2D models.
- Governing equations: 2D shallow water equations, numerical schemes (finite difference, finite volume) and stability criteria.
- Model inputs: DEM/LiDAR data, representation of buildings and roads, roughness, boundary and initial conditions.
- Overview and application of models: EPA SWMM, HEC-HMS, HEC-RAS 2D, MIKE+ and GIS-based rapid flood inundation models.
- Model calibration, validation, sensitivity and uncertainty analysis; performance indices (NSE, RMSE, PBIAS).
- Flood inundation mapping: depth, velocity and duration maps; satellite (SAR) data for flood extent validation.

Linked COs: CO3, CO4 **Number of Hours: 09**

Module-5

Urban Flood Risk Management:

- Flood hazard, exposure and vulnerability assessment; flood risk mapping and damage estimation using depth–damage curves.
- Structural measures: channel improvement, flood walls, diversion drains, detention storage and retrofitting of drainage systems.
- Sustainable Urban Drainage Systems (SUDS), Low Impact Development (LID) and Sponge City concepts: green roofs, permeable pavements, bio retention, rainwater harvesting and recharge.
- Non-structural measures: flood forecasting and early warning systems, real-time monitoring, flood zoning, land-use regulation and flood insurance.
- Institutional and policy framework: NDMA Guidelines on Management of Urban Flooding, SOPs, role of urban local bodies and community participation.
- Case studies on integrated urban flood management, urban lake restoration and climate-resilient city planning.

Linked COs: CO5, CO6 **Number of Hours: 08**

Suggested Learning Resources:

Textbooks

1. Chow, V. T., Maidment, D. R., & Mays, L. W. Applied Hydrology, McGraw Hill, latest edition.
2. Butler, D., Digman, C. J., Makropoulos, C., & Davies, J. W. Urban Drainage, CRC Press, 4th edition.
3. Zevenbergen, C., Cashman, A., Evelpidou, N., Pasche, E., Garvin, S., & Ashley, R. Urban Flood Management, CRC Press.
4. Mays, L. W. Stormwater Collection Systems Design Handbook, McGraw Hill.
5. K. Subramanya, Engineering Hydrology, McGraw Hill Education, latest edition.
6. Akan, A. O., & Houghtalen, R. J. Urban Hydrology, Hydraulics, and Stormwater Quality: Engineering Applications and Computer Modeling, John Wiley & Sons.
7. Jha, A. K., Bloch, R., & Lamond, J. Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century, The World Bank.

Reference Books

1. CPHEEO, Manual on Storm Water Drainage Systems, Ministry of Housing and Urban Affairs, Government of India, 2019.
2. NDMA, National Disaster Management Guidelines: Management of Urban Flooding, Government of India, 2010
3. Rossman, L. A. Storm Water Management Model (SWMM) User's Manual, U.S. Environmental Protection Agency, latest version.
4. US Army Corps of Engineers, HEC-HMS Technical Reference Manual and HEC-RAS 2D Modeling User's Manual, Hydrologic Engineering Center.
5. Price, R. K., &Vojinović, Z. Urban Hydroinformatics: Data, Models and Decision Support for Integrated Urban Water Management, IWA Publishing.
6. Woods Ballard, B., et al. The SuDS Manual (C753), CIRIA, London.
7. M. Hanif Chaudhry, Open-Channel Flow, Springer, latest edition.

Web links and Video Lectures (e-Resources)

1. Online Repositories: NPTEL courses on Hydrology and Urban Water/Stormwater Management (https://nptel.ac.in); NDMA urban flooding guidelines (https://ndma.gov.in); US EPA SWMM (https://www.epa.gov/water-research/storm-water-management-model-swmm); HEC-HMS/HEC-RAS (https://www.hec.usace.army.mil); India-WRIS (https://indiawris.gov.in); ISRO Bhuvan (https://bhuvan.nrsc.gov.in).
2. Software Tools: EPA SWMM (urban runoff and drainage network simulation), HEC-HMS (rainfall–runoff modelling), HEC-RAS 2D (flood inundation modelling), QGIS/ArcGIS (catchment delineation and flood mapping), Google Earth Engine (satellite-based flood extent mapping).

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are

listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1	**Urban catchment drainage case study:** Students delineate a local urban catchment (e.g., a city ward or valley) using GIS, estimate imperviousness and design peak runoff, and assess the adequacy of the existing storm water drains.	24
2	**IDF and design storm analysis:** Students derive IDF curves from observed rainfall data (IMD/state agencies) and develop design hyetographs for different return periods, including climate change scenarios.	24
3	**Mini project / group task:** Students work in groups to build an EPA SWMM or HEC-RAS 2D model of a small urban drainage network, simulate flooding and evaluate SUDS/LID mitigation options.	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	**Seminar presentation:** Each student presents on one topic such as a major Indian urban flood event, the sponge city concept, flood early warning systems or SAR-based flood mapping.	24
2	**Poster presentation:** Students create a poster on an urban flood mitigation measure (green roofs, permeable pavements, detention ponds, lake restoration), highlighting mechanism, design and benefits.	24

Sample rubrics for TW activities:

Criterion	**5**	**4**	**3**	**2**	**1**
Technical understanding	Explains concepts accurately and in depth	Minor gaps	Basic understanding	Partial understanding	Weak or incorrect
Relevance of application	Choice is highly appropriate and well justified	Mostly appropriate	Moderately relevant	Limited relevance	Not relevant
Analysis and comparison	Gives strong comparison with evidence	Good comparison	Some comparison	Minimal comparison	No meaningful analysis
Clarity of presentation	Very clear and well organized	Clear	Acceptable	Poorly organized	Unclear
References and data use	Uses reliable sources correctly	Uses adequate sources	Some sources used	Few sources	No proper sources

ENVIRONMENTAL IMPACT ASSESSMENT AND MANAGEMENT			
Course Code	**1MCWE205C**	Scheme	2026
Type of Course	**Professional Elective Course**	Semester	II
Teaching Hours/Week (L:T:P)	42 (3:0:0)	CIE Marks	50
Total Hours of Pedagogy per Semester CI (L/T):LI(P):TW&SL	90(42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Type of Examination (PCC):	Theory- CIE +SEE	Exam Hours	03

Course outcome (Course Skill Set):

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

1. CO1 (L2): Explain the concepts, evolution, legal provisions, and institutional framework of Environmental Impact Assessment (EIA) in India and globally.
2. CO2 (L2) Identify environmental attributes, define the scope, and establish baseline environmental conditions for developmental projects.
3. CO3 (L3) Apply appropriate methods and prediction models to assess impacts on air, water, noise, land, biological, and socio-economic environments.
4. CO4 (L3) Evaluate project alternatives and formulate Environmental Management Plans, including mitigation, monitoring, and risk management measures.
5. CO5 (L4) Prepare and review EIA reports and conduct public consultation in accordance with the EIA Notification, 2006 and its amendments.
6. CO6 (L5) Analyse EIA case studies and apply environmental management tools such as SEA, LCA, ISO 14001 EMS, and environmental audit.

Module-1

Introduction to EIA and Regulatory Framework:

- Introduction to EIA, Development Activity and Ecological Factor, Need for EIA Studies, Step-by-step procedures for conducting EIA- that includes, screening, scoping, impact analysis, mitigation measures, EIS, FONSI, Review, Monitoring, Public participation steps, Limitations of EIA, Environmental Setting, Objectives and Scope, Contents of EIA, Transnational effects of projects, Problems of EIA in developing countries
- EIA in India: Environment (Protection) Act, 1986, EIA Notification, 2006 and amendments, categorisation of projects (Category A, B1, and B2).

Linked COs: CO1, CO5 **Number of Hours: 8**

Module-2

EIA Process, Methodologies:

EIA Methodologies/Techniques of EIA, Simple/ descriptive/scaling checklist, simple and significance rated matrix, network analysis, cost-benefit analysis, overlay technique using RS an d GIS, simulation techniques- including physical, experimental and mathematical, environmental index including environmental factor identification, air quality index, water quality index, noise quality index methods and associated numerical.

Linked COs: CO2, CO3 **Number of Hours: 9**

Module-3

Prediction and Assessment of Environmental Impacts:

Assessment and Prediction of Impacts of ecological attributes and mitigation measures - Air, Surface Water, Noise, Soil and Groundwater and Biological Environment. Each of the assessment include: identification using different techniques (e.g. emission factor, pollutant list), baseline information (e.g. parameters and source of data), prevailing regulations and policies related to EIA, impact prediction using different techniques (filed/lab experiments- tracer, water/soil quality, noise levels, computer models like SWAT, QUAL2K, HNS, APRAC, NOISEMAPS, etc), Impact significance evaluation and possible mitigation measures for each of the components.

Linked COs: CO3, CO4 **Number of Hours: 9**

Module-4

Prediction and Assessment and Public Participation:

- Assessment and Prediction of Impacts of ecological attributes and mitigation measures - Social and cultural aspects (as similar to previous chapter).
- Introduction to public participation, its importance and limitations, role of public participation in EIA, Public hearing procedure and stakeholder engagement.

Linked COs: CO4, CO5 **Number of Hours: 8**

Module-5

Environmental Management Tools, Audit, and Case Studies:

- Life Cycle Assessment (ISO 14040/14044). Environmental Management Systems as per ISO 14001:2015. Environmental audit: types, procedures, and the Environmental Statement
- Environmental Clearance, Audit procedure
- Case studies of EIA for river valley and hydropower projects, thermal power plants, highways, mining, industrial estates, ports, and urban infrastructure, including water supply and sewerage projects.

Linked COs: CO5, CO6 **Number of Hours: 8**

Suggested Learning Resources:

Textbooks

1. Larry W. Canter, Environmental Impact Assessment, 2nd Edition, McGraw-Hill, 1996.
2. Y. Anjaneyulu and Valli Manickam, Environmental Impact Assessment Methodologies, 2nd Edition, BS Publications, 2011.
3. John Glasson and Riki Therivel, Introduction to Environmental Impact Assessment, 5th Edition, Routledge, 2019.
4. R. R. Barthwal, Environmental Impact Assessment, 2nd Edition, New Age International Publishers, 2012.
5. Christopher Wood, Environmental Impact Assessment: A Comparative Review, 2nd Edition, Pearson Education / Routledge, 2003.

Reference Books

1. Peter Morris and Riki Therivel (eds.), Methods of Environmental Impact Assessment, 3rd Edition, Routledge, 2009.
2. Judith Petts (ed.), Handbook of Environmental Impact Assessment, Vols. 1 and 2, Blackwell Science, 1999.
3. Ministry of Environment, Forest and Climate Change, EIA Notification, 2006 (S.O. 1533(E)) with amendments, and sector-specific EIA Guidance Manuals, Government of India.
4. Recent journal papers in Environmental Impact Assessment Review (Elsevier) and Impact Assessment and Project Appraisal (Taylor & Francis).

WeblinksandVideoLectures(e-Resources)

1. NPTEL/SWAYAM: Environmental Impact Assessment — online course covering EIA concepts, methods, and practice.
2. MoEF&CC Environmental Clearance: Notifications — EIA Notification, 2006, amendments, and office memoranda.
3. PARIVESH Portal — online environmental, forest, wildlife, and CRZ clearance system.
4. CPCB Technical Guidelines and SOPs — monitoring protocols useful for baseline studies.
5. IAIA: Impact Assessment — international best practice principles and resources on impact assessment.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching

- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	**TW-1:** EIA case study of a developmental project (e.g., highway, hydropower, or industrial project), identifying key environmental attributes and likely impacts.	24
2	**TW-2:** Prepare a baseline environmental monitoring plan (air, water, noise, soil, and ecology) with a sampling network for a selected project site.	24
3	**TW-3:** Apply an impact identification method (checklist, Leopold matrix, or network) and assess impact significance for a proposed project.	24
4	**TW-4:** Carry out air or water quality impact prediction using a dispersion or water quality model and interpret the results.	24
5	**TW-5:** Mini project: prepare an Environmental Management Plan, including mitigation, monitoring, and budget, for a selected project.	24

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	**SL-1:** NPTEL/SWAYAM module review on EIA fundamentals, methodologies, and the regulatory framework.	24
2	**SL-2:** Critical review of an EIA report available on the PARIVESH portal and preparation of a one-page technical note.	24
3	**SL-3:** Online study of the EIA Notification, 2006 and its recent amendments, and submission of a summary of key provisions.	24
4	**SL-4:** Short module on GIS/remote sensing or dispersion modelling tools for environmental impact assessment.	24

Sample rubrics for TW activities:

Criterion	Excellent (5)	Good (4)	Satisfactory (3)	Needs Improvement (2)	Weight
Problem understanding	Clear, accurate, and complete understanding of the project, its environmental setting, and regulatory context.	Minor gaps in context or framing.	Basic understanding with limited depth.	Incomplete or weak understanding.	20%
Technical relevance	Strong linkage to baseline data, impact identification, prediction methods, and mitigation measures.	Mostly relevant with minor omissions.	Some technical relevance, but generic.	Limited technical depth.	25%
Analysis and interpretation	Sound analysis with correct interpretation of impact predictions and significance.	Mostly correct with minor errors.	Partial analysis and interpretation.	Weak or incorrect analysis.	25%
Industry applicability	Recommendations are realistic, implementable, and compliant with EIA regulations and industry practice.	Good applicability with small gaps.	Moderate practicality.	Poor practical relevance.	20%
Presentation and documentation	Well-structured, concise, and professional.	Clear but slightly uneven.	Acceptable but basic.	Poorly organized or incomplete.	10%

CLIMATE CHANGE, MODELING AND ADAPTATION			
Course Code	**1MCWE205D**	Scheme	2026
Type of Course	**Professional Elective Course**	Semester	II
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per Semester CI (L/T):LI(P):TW&SL	90(42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Type of Examination (PCC):	Theory- CIE +SEE	Exam Hours	03

Course outcome (Course Skill Set):

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

1. CO1 (L2): Explain the climate system, the science of greenhouse-gas forcing, and observed trends in climate variables at global, national, and regional scales.
2. CO2 (L3): Analyze climate data and interpret the outputs of global and regional climate models under different emission and socio-economic scenarios.
3. CO3 (L3): Apply dynamical and statistical downscaling and bias-correction techniques to develop regional climate projections.
4. CO4 (L4): Assess the impacts of climate change on water resources, hydrological extremes, and infrastructure using hydrological models.
5. CO5 (L5): Formulate adaptation and mitigation strategies and policy frameworks for climate-resilient water and infrastructure systems.

Module-1

- Weather and Climate, The Climate System, Processes, Temporal Variations, Statistical properties of Climate, Spatial Scales on Climate Variations.
- Observations Atmosphere, Cryosphere, Ocean, Carbon Cycle.

Linked COs: CO1 **Number of Hours: 8**

Module-2

- Paleoclimate - Methods, The Last Two Millennia, The Holocene, The Ice Ages, Milankovitch Theory.
- Theory : Electromagnetic Radiation: Interaction of electromagnetic radiation with matter, The Greenhouse
- Effect, Earth's Energy Budget, Radioactive Forcing, Feedback Processes, and Climate Sensitivity.

Linked COs: CO2 **Number of Hours: 09**

Module-3

- **Biogeochemical cycles:** The Natural Carbon Cycle, b) Anthropogenic Carbon, c) Carbonate Chemistry and Ocean Acidification.
- d) Processes:
  - Atmospheric Circulation, ii) The Hydrologic Cycle, iii) Ocean Circulation.

Linked COs: CO3 **Number of Hours: 08**

Module-4

Models:

- a) Construction: boundary conditions, initial conditions, zero-dimensional (OD) Energy Balance Model (EBM),one-dimensional EBM (1D-EBM). Three-dimensional GCMs, regional climate models.
- b) Evaluation.
- C) Applications: Pale climate model studies, Detection and attribution studies.

Linked COs: CO4 **Number of Hours: 09**

Module-5

- **Impacts:**

Projections: Uncertainties, b) Ecosystems: Vegetation models, Wildfires, Ocean ecosystems, c) Long-Term Changes, d) Regional Changes, e) Extremes, f) Impacts on Humans.

- **Economics**
- Economics and the climate change challenge: Understanding incentives and policies.

Linked COs: CO5 **Number of Hours: 08**

Suggested Learning Resources:

Textbooks

1. Barry R.G., and Chorley R.L., "Atmosphere, Weather and Climate", 4th Edition, ELBS Publication.
2. Bolin B., (Ed.), "Carbon Cycle Modelling", John Wiley and Sons Publications.
3. Introduction to Climate Science by Andreas Schmittner (online Edition)
4. Mujumdar, P. P. and Nagesh Kumar, D. Floods in a Changing Climate: Hydrologic Modeling, Cambridge University Press.
5. Maraun, D. and Widmann, M. Statistical Downscaling and Bias Correction for Climate Research, Cambridge University Press.
6. Barry, R. G. and Hall-McKim, E. A. Essentials of the Earth's Climate System, Cambridge University Press.

Reference Books

1. IPCC, Climate Change 2021: The Physical Science Basis, Contribution of Working Group I to the Sixth Assessment Report, Cambridge University Press.
2. IPCC, Climate Change 2022: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Sixth Assessment Report, Cambridge University Press.
3. Krishnan, R. et al. (Eds.), Assessment of Climate Change over the Indian Region, Ministry of Earth Sciences, Government of India, Springer.
4. Goosse, H. Climate System Dynamics and Modelling, Cambridge University Press.
5. Washington, W. M. and Parkinson, C. L. An Introduction to Three-Dimensional Climate Modeling, University Science Books.

Web links and Video Lectures (e-Resources)

1. Online Repositories: IPCC AR6 reports (www.ipcc.ch), CMIP6 data through the Earth System Grid Federation (ESGF), CORDEX South Asia data, IMD gridded rainfall and temperature data, NPTEL courses on climate science, hydrology, and water resources.
2. Software Tools: Python / R (climate data analysis), Climate Data Operators (CDO), SDSM (statistical downscaling), CMhyd (bias correction), QGIS, and SWAT / HEC-HMS (hydrological modelling).

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

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Assessment Structure (both CIE and SEE)

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Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation

CIE [25+25=50 marks]
A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.
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Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	Analyze long-term IMD rainfall and temperature data for a selected river basin or district to detect trends and change points using the Mann-Kendall test and Sen's slope estimator.	24
2	Downscale and bias-correct CMIP6 projections for a selected catchment under two SSP scenarios and assess the resulting changes in runoff using a hydrological model.	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	**CMIP6 Model Performance Evaluation:** Compare the historical simulations of selected CMIP6 GCMs with IMD observed data over a chosen region using statistical performance indicators, and rank the models for use in impact studies.	24
2	**Climate-Adjusted IDF Curves:** Develop intensity-duration-frequency (IDF) curves for a selected city from observed rainfall and update them using downscaled future projections to evaluate implications for urban storm-water drainage design.	24
3	Review the Karnataka State Action Plan on Climate Change (or any State Action Plan) and prepare a report on water-sector adaptation measures.	24
4	Complete a MOOC or online course on climate change science or adaptation (e.g., NPTEL, Coursera, UN CC:Learn) and submit a brief report on its application.	24

Sample rubrics for TW activities:

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear climate problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with	Limited data or partial method.	Inadequate or incorrect method.

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
		minor issues.		
Analysis	Robust interpretation and valid results.	Generally, sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

INTEGRATED WATERSHED MANAGEMENT			
Course Code	**1MCWE205E**	Scheme	2026
Type of Course	**Professional Elective Course**	Semester	II
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per Semester CI (L/T):LI(P):TW&SL	90(42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Type of Examination (PCC):	Theory- CIE +SEE	Exam Hours	03

Course outcome (Course Skill Set):

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

- CO1 (L2): Explain the concepts, characteristics, and classification of watersheds and the need for integrated and participatory watershed management.
- CO2 (L3): Analyse hydrological processes, runoff, soil erosion, and sediment yield in a watershed using empirical and modern methods.
- CO3 (L3): Design suitable soil and water conservation measures and water harvesting structures for watershed treatment.
- CO4 (L4): Apply remote sensing, GIS, and hydrological models for watershed delineation, characterization, and prioritization.
- CO5 (L4): Formulate integrated watershed development plans addressing land use, agriculture, forestry, livestock, and livelihoods.
- CO6 (L5): Evaluate watershed programmers for socio-economic, environmental, and climate-resilience outcomes and long-term sustainability.

Module-1

Watershed Concepts and Characterization:

- Watershed: definition, concept, and components; classification of watersheds based on size, shape, land use, and drainage pattern; watershed codification (Watershed Atlas of India).
- Morphometric analysis: linear, areal, and relief aspects; stream ordering, drainage density, bifurcation ratio, form factor, and their hydrological significance.
- Watershed problems in India: land degradation, water scarcity, floods, droughts, and deforestation; need, objectives, and principles of integrated watershed management.
- Participatory watershed management: stakeholders, watershed committees, user groups, role of NGOs, Panchayati Raj Institutions, and women in watershed programmes.

Linked COs: CO1, CO4. **Number of Hours: 08**

Module-2

Watershed Hydrology and Soil Erosion:

- Hydrologic cycle and water balance of a watershed; rainfall analysis, infiltration, and evapotranspiration.
- Runoff estimation: factors affecting runoff, rational method, SCS-Curve Number method, and unit hydrograph concept for small watersheds.
- Soil erosion: types, agents, and mechanics of water and wind erosion; factors affecting erosion; estimation of soil loss using USLE, RUSLE, and MUSLE.
- Sediment yield, sediment delivery ratio, and reservoir sedimentation; sediment yield index and its use in watershed planning.

Linked COs: CO2, CO3. **Number of Hours: 08**

Module-3

Soil and Water Conservation and Water Harvesting:

- Agronomic and biological measures: contour farming, strip cropping, mulching, cover crops, vegetative barriers, agroforestry, and afforestation.
- Mechanical measures: contour bunds, graded bunds, bench terraces, contour trenches, and diversion drains; design principles of bunds and terraces.

- Gully and ravine control: classification of gullies, check dams, loose boulder structures, gabions, and drop structures.
- Water harvesting and groundwater recharge: in-situ harvesting, farm ponds, percolation tanks, nala bunds, recharge pits and shafts, rooftop rainwater harvesting, and springshed management.

Linked COs: CO3, CO5. **Number of Hours: 09**

Module-4

Geospatial Techniques and Watershed Modelling:

- Remote sensing and GIS in watershed management: DEM-based watershed delineation, drainage extraction, slope, soil, and land use/land cover mapping.
- Prioritization of sub-watersheds using morphometric parameters, sediment yield index, and multi-criteria decision analysis.
- Hydrological and erosion models for watersheds: overview of SWAT, HEC-HMS, and GIS-based soil loss modelling; data requirements, calibration, and validation.
- Watershed monitoring and evaluation using satellite data, UAVs, and decision support systems; national geoportals (Bhuvan) for watershed data.

Linked COs: CO2, CO4, CO6. **Number of Hours: 08**

Module-5

Integrated Planning, Programmes, and Sustainability:

- Integrated watershed development planning: land capability classification, crop planning, horticulture, pasture and fodder development, livestock, fisheries, and conjunctive use of water.
- Watershed development programmes in India: Common Guidelines for Watershed Development Projects, IWMP, WDC-PMKSY and New Generation Watershed Development Projects (WDC-PMKSY 2.0), and convergence with MGNREGA.
- Socio-economic and livelihood aspects; cost-benefit analysis, impact assessment, and sustainability indicators; climate change adaptation and drought proofing through watershed interventions.
- Case studies: Ralegan Siddhi, Hiware Bazar, Sukhomajri, and Karnataka Watershed Development Project (Sujala).

Linked COs: CO5, CO6. **Number of Hours: 09**

Suggested Learning Resources:

Textbooks:

1. J. V. S. Murty, Watershed Management, 2nd Edition, New Age International Publishers.
2. V. V. Dhruva Narayana, G. Sastry, and U. S. Patnaik, Watershed Management, ICAR Publication, New Delhi.
3. Ghanshyam Das, Hydrology and Soil Conservation Engineering: Including Watershed Management, 2nd Edition, PHI Learning.

Reference Books:

1. R. Suresh, *Soil and Water Conservation Engineering*, Standard Publishers Distributors, New Delhi.
2. K. N. Brooks, P. F. Ffolliott, and J. A. Magner, *Hydrology and the Management of Watersheds*, 4th Edition, Wiley-Blackwell.
3. V. V. N. Murty and M. K. Jha, *Land and Water Management Engineering*, 6th Edition, Kalyani Publishers.
4. G. O. Schwab, D. D. Fangmeier, W. J. Elliot, and R. K. Frevert, *Soil and Water Conservation Engineering*, 4th Edition, John Wiley & Sons.

Guidelines and Manuals

1. Department of Land Resources, MoRD, GoI, *Common Guidelines for Watershed Development Projects*, 2008 (Revised 2011).
2. Department of Land Resources, MoRD, GoI, *Guidelines for New Generation Watershed Development Projects (WDC-PMKSY 2.0)*, 2021.
3. Soil and Land Use Survey of India, *Watershed Atlas of India*, Ministry of Agriculture and Farmers Welfare, GoI.
4. Gurmel Singh et al., *Manual of Soil and Water Conservation Practices*, CSWCRTI (ICAR-IISWC) Dehradun, Oxford & IBH Publishing.

Web links and Video Lectures (e-Resources) :

7. NPTEL course: Watershed Management, Prof. T. I. Eldho, IIT Bombay - https://archive.nptel.ac.in/courses/105/101/105101010/
8. Department of Land Resources, GoI - WDC-PMKSY guidelines and resources: https://dolr.gov.in/en/wdcpmksy/
9. ISRO Bhuvan geoportal (watershed, land use, and DEM data): https://bhuvan.nrsc.gov.in
10. Software tools: QGIS (watershed delineation and mapping), SWAT / QSWAT (watershed hydrology and sediment modelling), HEC-HMS (rainfall-runoff modelling).

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	**TW1-Watershed Delineation and Morphometric Analysis:** Students shall delineate a watershed near the institute or in their region using DEM and GIS, compute linear, areal, and relief parameters, and interpret their hydrological significance.	24
2	**TW2-Runoff and Soil Loss Estimation:** Students shall estimate runoff using the SCS-CN method and annual soil loss using USLE/RUSLE for a selected watershed and identify critical erosion-prone areas.	24
3	**TW3-Design of Conservation and Water Harvesting Structures:** Students shall propose and design suitable soil and water	24

	conservation measures (bunds, trenches, check dams, farm ponds, or percolation tanks) with sketches, locations, and cost estimates.	
4	**TW4-Integrated Watershed Development Plan:** Students shall prepare an integrated treatment plan for a micro-watershed covering land capability, crop planning, water harvesting, livelihood activities, and a cost-benefit assessment.	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	**SL1-Case Study on a Successful Watershed:** Students shall study a successful watershed project in India (e.g., Ralegan Siddhi, Hiware Bazar, Sujala) and summarize the interventions, community participation, outcomes, and lessons learned.	24
2	**SL2-Watershed Programme Review:** Students shall review the Common Guidelines and WDC-PMKSY 2.0 guidelines and prepare a note on institutional arrangements, project phases, funding norms, and monitoring mechanisms.	24
3	**SL3-MOOC / Geospatial Tool Learning:** Students shall complete selected modules of the NPTEL Watershed Management course or a QGIS/SWAT tutorial and submit a short report on its application to watershed planning.	24

Sample rubrics for TW activities:

Criterion	**Excellent 4**	**Good 3**	**Satisfactory 2**	**Needs Improvement 1**
Understanding of watershed concepts	Correctly identifies and explains watershed issues with strong technical clarity.	Identifies the issues well with minor gaps.	Basic identification with limited explanation.	Incorrect or incomplete understanding.
Technical accuracy	Analysis, computations, and designs are technically sound.	Minor technical or computational errors.	Several conceptual gaps.	Major technical errors.
Sustainability and community consideration	Clearly integrates sustainability, community participation, and climate resilience.	Adequate sustainability linkage.	Limited sustainability reference.	No sustainability linkage.
Presentation and organization	Professional format, clear maps/diagrams/tables, logical flow.	Well organized with minor formatting issues.	Acceptable but uneven presentation.	Poorly organized or incomplete.
Practical relevance	Strong field applicability and justified recommendations.	Good practical relevance.	Limited application.	No meaningful practical connection.

Rubrics for SL Activities:

Criterion	**Excellent 4**	**Good 3**	**Satisfactory 2**	**Needs Improvement 1**
Quality of literature/case review	Uses relevant and credible sources with strong synthesis.	Good sources with adequate synthesis.	Limited sources, basic summary.	Weak or missing sources.
Technical content	Accurate, complete, and conceptually strong.	Mostly accurate with minor omissions.	Partial coverage of content.	Inaccurate or incomplete content.
Independent learning	Shows clear self-learning and critical thinking.	Some evidence of independent effort.	Limited independent analysis.	Minimal effort or copied content.
Sustainability focus	Strong emphasis on sustainable watershed and natural resource practices.	Moderate sustainability linkage.	Weak sustainability linkage.	No sustainability focus.
Communication quality	Clear, concise, and professionally presented.	Mostly clear with minor issues.	Understandable but inconsistent.	Poorly written or disorganized.

WASTEWATER RECLAMATION AND REUSE			
Course Code	**1MCWE206A**	Scheme	2026
Type of Course	**Professional Elective Course**	Semester	II
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per Semester CI (L/T):LI(P):TW&SL	90(42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Type of Examination (PCC):	Theory- CIE +SEE	Exam Hours	03

Course outcome (Course Skill Set):

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

1. CO1 (L2): Explain the need, potential and global/Indian scenario of wastewater reclamation and reuse, along with the associated health and environmental risks.
2. CO2 (L3): Characterize wastewater and treated effluent, and interpret water quality criteria, standards and guidelines applicable to various reuse applications.
3. CO3 (L4): Select and design appropriate advanced treatment processes such as filtration, membrane processes, advanced oxidation and disinfection for producing reclaimed water.
4. CO4 (L4): Plan reuse schemes for agricultural, landscape, industrial, urban non-potable and groundwater recharge applications, including storage and distribution systems.
5. CO5 (L5): Evaluate potable reuse, decentralized and greywater recycling systems with respect to reliability, multiple-barrier concept and public acceptance.
6. CO6 (L5): Assess the economic, regulatory, energy and resource-recovery aspects of reuse projects through planning tools, risk assessment and case studies.

Module-1

Introduction to Wastewater Reclamation and Reuse:

- Water scarcity and the role of reclaimed water in integrated water resources management; definitions: reclamation, recycling, reuse, planned and unplanned (de facto) reuse.
- Historical development and current status of water reuse in India and worldwide; categories of reuse applications and the circular economy approach to used water.
- Wastewater constituents of concern for reuse: pathogens, nutrients, salts, heavy metals, trace organics and emerging contaminants (PPCPs, EDCs, microplastics).
- Health and environmental concerns; water quality criteria, standards and guidelines for reuse: CPCB standards, National Framework on Safe Reuse of Treated Water (NMCG), USEPA and WHO guidelines.

Linked COs: CO1, CO2. **Number of Hours: 08**

Module-2

Treatment Technologies for Water Reclamation:

- Review of conventional secondary treatment; treatment trains and levels of treatment for different reuse applications; process reliability.
- Removal of residual suspended solids: depth filtration, surface filtration, dissolved air flotation; membrane processes: MF, UF, NF, RO, electrodialysis and membrane bioreactors (MBR).
- Removal of dissolved constituents: adsorption on activated carbon, ion exchange, chemical precipitation, advanced oxidation processes and nutrient removal/recovery.
- Disinfection of reclaimed water: chlorination, chloramination, UV radiation and ozonation; disinfection by-products; concentrate (brine) management and disposal

Linked COs: CO2, CO3. **Number of Hours: 09**

Module-3

Agricultural, Landscape and Industrial Reuse:

- Agricultural irrigation with reclaimed water: water quality parameters (salinity, SAR, specific ions, trace elements, nutrients), crop tolerance and irrigation methods.
- Landscape irrigation of parks, golf courses and urban green spaces; soil and groundwater impacts; health protection measures and buffer zones.
- Industrial reuse: cooling water, boiler feed water and process water; quality requirements, scaling, corrosion, biofouling control and zero liquid discharge (ZLD).
- Environmental and recreational uses: habitat restoration, stream flow augmentation, recreational impoundments and aquaculture.

Linked COs: CO2, CO4. **Number of Hours: 08**

Module-4

Urban Non-Potable, Groundwater Recharge and Potable Reuse:

- Urban non-potable reuse: toilet flushing, fire protection, vehicle washing, construction and dust control; dual distribution systems and cross-connection control.
- Storage of reclaimed water: open and closed reservoirs, water quality changes during storage and distribution, operation and maintenance.
- Groundwater recharge with reclaimed water: surface spreading, vadose zone and direct injection methods; soil aquifer treatment (SAT) and aquifer storage and recovery.
- Indirect and direct potable reuse: multiple-barrier concept, advanced water purification, monitoring and public perception; decentralised systems and greywater recycling in buildings.

Linked COs: CO4, CO5. **Number of Hours: 09**

Module-5

Planning, Management and Case Studies:

- Planning of water reuse projects: market assessment, facilities planning, siting of reclamation plants and stakeholder participation.
- Economic and financial analysis: cost estimation, pricing of reclaimed water, cost recovery and life-cycle cost; energy use and resource recovery (water, energy, nutrients).
- Microbial and chemical risk assessment (QMRA), sanitation safety planning, institutional and legal framework, public outreach and acceptance.
- Case studies: NEWater (Singapore), Orange County GWRS (USA), Windhoek (Namibia), and Indian examples such as Chennai, Bengaluru and Nagpur-Koradi industrial reuse.

Linked COs: CO5, CO6. **Number of Hours: 08**

Suggested Learning Resources:

Textbooks:

1. Metcalf & Eddy (T. Asano, F. L. Burton, H. L. Leverenz, R. Tsuchihashi and G. Tchobanoglous), Water Reuse: Issues, Technologies, and Applications, 1st Edition, McGraw-Hill Education.
2. Metcalf & Eddy (G. Tchobanoglous, H. D. Stensel, R. Tsuchihashi and F. L. Burton), Wastewater Engineering: Treatment and Resource Recovery, 5th Edition, McGraw-Hill Education.
3. T. Asano (Editor), Wastewater Reclamation and Reuse, Water Quality Management Library Vol. 10, CRC Press.

Reference Books:

1. V. Lazarova and A. Bahri (Editors), Water Reuse for Irrigation: Agriculture, Landscapes, and Turf Grass, CRC Press.
2. V. Lazarova, T. Asano, A. Bahri and J. Anderson (Editors), Milestones in Water Reuse: The Best Success Stories, IWA Publishing.
3. S. J. Judd, The MBR Book: Principles and Applications of Membrane Bioreactors for Water and Wastewater Treatment, 2nd Edition, Butterworth-Heinemann.
4. CPHEEO, Manual on Sewerage and Sewage Treatment Systems (Parts A, B and C), Ministry of Housing and Urban Affairs, Government of India, 2013.

Standards and Codes

1. Ministry of Jal Shakti / NMCG, National Framework on the Safe Reuse of Treated Water, Government of India,

2022.
2. USEPA, 2012 Guidelines for Water Reuse, EPA/600/R-12/618, U.S. Environmental Protection Agency.
3. WHO, Guidelines for the Safe Use of Wastewater, Excreta and Greywater (Volumes 1 to 4), World Health Organization, 2006.
4. IS 11624:1986, Guidelines for the Quality of Irrigation Water; CPCB effluent discharge standards under the Environment (Protection) Rules, 1986.

Web links and Video Lectures (e-Resources) :

1. NPTEL/SWAYAM course: Wastewater Treatment and Recycling (IIT Kharagpur) - https://onlinecourses.nptel.ac.in/noc25_ce116/preview; USEPA 2012 Guidelines for Water Reuse - https://www.epa.gov/sites/default/files/2019-08/documents/2012-guidelines-water-reuse.pdf; WHO Guidelines for Safe Use of Wastewater, Greywater and Excreta - https://www.who.int/teams/environment-climate-change-and-health/water-sanitation-and-health/sanitation-safety/guidelines-for-safe-use-of-wastewater-greywater-and-excreta
2. Software Tools: EPA SWMM / WaterGEMS (reclaimed water distribution), WAVE / ROSA / IMSDesign (membrane system design), GPS-X / BioWin (treatment process simulation), and QMRA tools for health risk assessment.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	**TW1-Reuse Potential Assessment:** Students shall survey a local STP or institutional campus, quantify treated effluent availability, identify	24

	potential reuse demands, and prepare a supply-demand matching report.	
2	**TW2-Treatment Train Selection:** Students shall select and justify a tertiary treatment train for a specified reuse application (irrigation, industrial cooling or toilet flushing) based on quality targets, cost and energy.	24
3	**TW3-Design of Reclamation Unit:** Students shall carry out the process design of a tertiary unit (filtration/UF/RO/UV disinfection) for a given flow, with sketches, design calculations and O&M requirements.	24
4	**TW4-Water Reuse Project Plan:** Students shall prepare a reuse plan for an urban area or industry including storage, dual distribution, monitoring, cost estimation and stakeholder communication.	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	**SL1-Case Study on Water Reuse:** Students shall study a successful reuse project (e.g., NEWater, Orange County GWRS, Chennai/Bengaluru reuse schemes) and summarise the treatment scheme, regulations, costs and lessons learned.	24
2	**SL2-Emerging Technology Review:** Students shall review one emerging reclamation technology (MBR, forward osmosis, AOP, constructed wetlands) explaining its principle, performance, limitations and relevance to reuse.	24
3	**SL3-Standards and Guidelines Review:** Students shall prepare a comparative note on reuse water quality standards of India (CPCB, National Framework on Safe Reuse), USEPA and WHO for different reuse categories.	24

Sample rubrics for TW activities:

Criterion	Excellent 4	Good 3	Satisfactory 2	Needs Improvement 1
Understanding of reuse concepts	Correctly identifies and explains the issue with strong technical clarity.	Identifies the issue well with minor gaps.	Basic identification with limited explanation.	Incorrect or incomplete understanding.
Technical accuracy	Methods and observations are technically sound.	Minor technical errors.	Several conceptual gaps.	Major technical errors.
Sustainability and health-risk consideration	Clearly integrates public health safety, resource recovery and sustainability.	Adequate sustainability linkage.	Limited sustainability reference.	No sustainability linkage.
Presentation and organization	Professional format, clear diagrams/tables, logical flow.	Well organized with minor formatting issues.	Acceptable but uneven presentation.	Poorly organized or incomplete.
Practical relevance	Strong real-world applicability and justified recommendations.	Good practical relevance.	Limited application.	No meaningful practical connection.

Rubrics for SL Activities:

Criterion	**Excellent 4**	**Good 3**	**Satisfactory 2**	**Needs Improvement 1**
Quality of literature/case review	Uses relevant and credible sources with strong synthesis.	Good sources with adequate synthesis.	Limited sources, basic summary.	Weak or missing sources.
Technical content	Accurate, complete, and conceptually strong.	Mostly accurate with minor omissions.	Partial coverage of content.	Inaccurate or incomplete content.
Independent learning	Shows clear self-learning and critical thinking.	Some evidence of independent effort.	Limited independent analysis.	Minimal effort or copied content.
Reuse and sustainability focus	Strong emphasis on safe reuse and sustainable water management practices.	Moderate sustainability linkage.	Weak sustainability linkage.	No sustainability focus.
Communication quality	Clear, concise, and professionally presented.	Mostly clear with minor issues.	Understandable but inconsistent.	Poorly written or disorganized.

ENVIRONMENTAL DATA ANALYTICS			
Course Code	**1MCWE206B**	Scheme	2026
Type of Course	**Professional Elective Course**	Semester	II
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per Semester CI (L/T):LI(P):TW&SL	90(42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Type of Examination (PCC):	Theory- CIE +SEE	Exam Hours	03

Course outcome (Course Skill Set):

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

1. CO1 (L2): Explain the sources, types and characteristics of environmental data and the principles of monitoring network design and data quality assurance.
2. CO2 (L3): Apply data pre-processing, exploratory data analysis and visualization techniques to air, water, soil and climate datasets.
3. CO3 (L3): Apply parametric, non-parametric, regression and multivariate statistical methods to interpret environmental data and assess compliance.
4. CO4 (L4): Analyze time-series and spatial environmental data using trend analysis, forecasting, geostatistics, GIS and remote sensing tools.
5. CO5 (L5): Develop machine learning based predictive and classification models for environmental quality forecasting and management.
6. CO6 (L6): Evaluate environmental indices, model uncertainty and data-driven decision-support outputs to communicate insights for sustainable environmental management.

Module-1

Environmental Data: Sources, Monitoring and Quality:

- Nature of environmental data: air, water, soil, noise, climate, hydrological, biodiversity and solid waste data; scales of measurement; spatial and temporal attributes of environmental variables.
- Data sources: CPCB/SPCB monitoring networks (NAMP, NWMP, CAAQMS), IMD, CWC and India-WRIS, satellite data products, low-cost sensors, IoT networks and citizen science.
- Monitoring network design: sampling strategies (simple random, stratified, systematic, composite), sampling frequency, sample size estimation and representativeness.
- Data quality assurance and quality control (QA/QC), detection limits and censored (below-detection-limit) data, metadata, FAIR data principles and environmental data management.

Linked COs: CO1, CO2. **Number of Hours: 08**

Module-2

Data Pre-processing, Exploratory Analysis and Visualization:

- Data cleaning: handling of missing data and imputation methods, outlier detection (IQR, z-score, Grubbs test), data transformation, normalization and aggregation.
- Descriptive statistics and probability distributions common in environmental data: normal, log-normal, gamma, Weibull and extreme value distributions; goodness-of-fit tests.
- Exploratory data analysis: histograms, box plots, Q-Q plots, scatter-plot matrices, correlation analysis, wind roses and pollution roses, heat maps and calendar plots.
- Computational tools: Python (Pandas, NumPy, Matplotlib, Seaborn), R (openair, tidyverse) and spreadsheets for environmental data handling; interactive dashboards.

Linked COs: CO2, CO3. **Number of Hours: 08**

Module-3

Statistical Methods for Environmental Data:

- Estimation and hypothesis testing: confidence intervals, t-test, ANOVA, chi-square test; non-parametric tests (Mann-Whitney, Wilcoxon, Kruskal-Wallis) for skewed environmental data.
- Correlation and regression: simple and multiple linear regression, non-linear regression, model diagnostics and residual analysis; pollutant concentration-emission and dose-response relationships.
- Multivariate methods: principal component analysis, factor analysis, cluster analysis and discriminant analysis; introduction to receptor models and source apportionment.
- Environmental indices and compliance: Air Quality Index (AQI), Water Quality Index (WQI), exceedance analysis against NAAQS and IS 10500 standards, percentile-based compliance assessment.

Linked COs: CO3, CO6. **Number of Hours: 09**

Module-4

Time-Series and Spatial Data Analytics:

- Time-series components: trend, seasonality, cycles and noise; smoothing and moving averages; autocorrelation; Mann-Kendall trend test and Sen's slope estimator.
- Forecasting models: exponential smoothing, ARIMA and SARIMA; extreme value analysis and return periods for rainfall, floods and pollution episodes.
- Spatial data analytics: GIS fundamentals, vector and raster data, spatial interpolation (IDW, kriging), variogram analysis and spatial autocorrelation (Moran's I).
- Remote sensing for environmental monitoring: Landsat, Sentinel and MODIS products, NDVI, land use/land cover change, surface water and aerosol mapping using Google Earth Engine.

Linked COs: CO4, CO6. **Number of Hours: 08**

Module-5

Machine Learning, Big Data and Decision Support:

- Machine learning workflow: feature engineering, train-test split, cross-validation, hyperparameter tuning and performance metrics (RMSE, MAE, R^2, accuracy, confusion matrix).
- Supervised learning (decision trees, random forest, support vector machines, artificial neural networks) and unsupervised learning (k-means, hierarchical clustering); applications to air quality prediction, water quality classification and flood forecasting.
- Big environmental data: IoT sensor networks, cloud platforms, digital twins; uncertainty and sensitivity analysis of data-driven models.
- Decision support systems, data-driven environmental impact assessment, reporting and visualization for stakeholders, open data policy and ethics; case studies on urban air quality, river water quality and climate data.

Linked COs: CO5, CO6. **Number of Hours: 09**

Suggested Learning Resources:

Textbooks:

1. Richard O. Gilbert, Statistical Methods for Environmental Pollution Monitoring, John Wiley & Sons (Van Nostrand Reinhold).
2. Steven P. Millard and Nagaraj K. Neerchal, Environmental Statistics with S-PLUS, CRC Press.
3. Dennis R. Helsel, Robert M. Hirsch, Karen R. Ryberg, Stacey A. Archfield and Edward J. Gilroy, Statistical Methods in Water Resources, U.S. Geological Survey Techniques and Methods, Book 4, Chapter A3, 2020.

Reference Books:

1. Walter W. Piegorsch and A. John Bailer, *Analyzing Environmental Data*, 1st Edition, John Wiley & Sons.
2. Daniel S. Wilks, *Statistical Methods in the Atmospheric Sciences*, 4th Edition, Elsevier.
3. Gareth James, Daniela Witten, Trevor Hastie and Robert Tibshirani, *An Introduction to Statistical Learning (with Applications in Python)*, Springer.
4. Chris Brunsdon and Lex Comber, *An Introduction to R for Spatial Analysis and Mapping*, 2nd Edition, SAGE Publications.
5. Dennis R. Helsel, *Statistics for Censored Environmental Data Using Minitab and R*, 2nd Edition, John Wiley & Sons.

Standards and Guidelines

1. CPCB, Guidelines for the Measurement of Ambient Air Pollutants (NAAQS Monitoring and Analysis Guidelines), Volumes I and II, 2011.
2. CPCB, National Air Quality Index, Control of Urban Pollution Series CUPS/82/2014-15.
3. IS 10500:2012, Drinking Water – Specification; IS 3025 (all parts), Methods of Sampling and Test (Physical and Chemical) for Water and Wastewater.
4. National Ambient Air Quality Standards (NAAQS), CPCB Notification, 2009.

Web links and Video Lectures (e-Resources) :

1. Online Repositories: CPCB Air Quality Data and Resources (https://airquality.cpcb.gov.in), India-WRIS water resources information system (https://indiawris.gov.in), USGS Statistical Methods in Water Resources (https://pubs.usgs.gov/tm/04/a03/tm4a3.pdf), NPTEL course on "Python for Data Science" (https://onlinecourses.nptel.ac.in/noc24_cs54/preview).
2. Software Tools: Python (Pandas, NumPy, SciPy, scikit-learn, statsmodels), R and RStudio (openair package), QGIS for spatial analysis, Google Earth Engine for satellite data processing.

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Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	**TW1-Environmental Dataset Exploration Report:** Students shall obtain a real monitoring dataset (e.g., CPCB CAAQMS or water quality data), perform cleaning, QA/QC checks and exploratory analysis, and present key findings through visualizations.	24

2	**TW2-Statistical Compliance Assessment:** Students shall compute AQI/WQI for a selected city or river stretch, test for significant differences across stations or seasons, and assess compliance with prescribed standards.	24
3	**TW3-Trend and Spatial Analysis:** Students shall carry out Mann-Kendall trend analysis on long-term climate or pollution data and prepare interpolated spatial maps using GIS, interpreting the observed patterns.	24
4	**TW4-Predictive Model Development:** Students shall develop and validate a machine learning model to forecast an environmental parameter (e.g., PM2.5, DO, rainfall-runoff) and report model performance and uncertainty.	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	**SL-1: Environmental Data Sources Review:** Students shall review national and global environmental data repositories, and summarize data availability, resolution, quality issues and access procedures.	24
2	**SL-2: MOOC on Data Analytics:** Students shall complete a relevant MOOC module (e.g., NPTEL Python for Data Science) and submit a short application note using an environmental dataset.	24
3	**SL-3: Case Study on Data-Driven Environmental Management:** Students shall study a published case of data analytics or machine learning applied to air, water or climate management, and summarize the methods, results and lessons learned.	24

Sample rubrics for TW activities:

Criterion	**Excellent 4**	**Good 3**	**Satisfactory 2**	**Needs Improvement 1**
Understanding of environmental data concepts	Correctly identifies data characteristics and methods with strong technical clarity.	Good understanding with minor gaps.	Basic understanding with limited explanation.	Incorrect or incomplete understanding.
Data handling and analytical accuracy	Data processing and analysis are technically sound and correctly executed.	Minor errors in analysis.	Several methodological gaps.	Major analytical errors.
Interpretation of results	Insightful interpretation linked to environmental standards and management.	Adequate interpretation.	Limited interpretation.	No meaningful interpretation.
Presentation and visualization	Professional format, clear charts/maps/tables, logical flow.	Well organized with minor formatting issues.	Acceptable but uneven presentation.	Poorly organized or incomplete.
Practical relevance	Strong real-world applicability and justified recommendations.	Good practical relevance.	Limited application.	No meaningful practical connection.

Rubrics for SL Activities:

Criterion	**Excellent 4**	**Good 3**	**Satisfactory 2**	**Needs Improvement 1**
Quality of literature/data review	Uses relevant and credible sources with strong synthesis.	Good sources with adequate synthesis.	Limited sources, basic summary.	Weak or missing sources.
Technical content	Accurate, complete, and conceptually strong.	Mostly accurate with minor omissions.	Partial coverage of content.	Inaccurate or incomplete content.
Independent learning	Shows clear self-learning and critical thinking.	Some evidence of independent effort.	Limited independent analysis.	Minimal effort or copied content.
Environmental relevance	Strong linkage to environmental problems and data-driven solutions.	Moderate environmental linkage.	Weak environmental linkage.	No environmental focus.
Communication quality	Clear, concise, and professionally presented.	Mostly clear with minor issues.	Understandable but inconsistent.	Poorly written or disorganized.

INDUSTRIAL WASTEWATER MANAGEMENT AND AUDIT			
Course Code	**1MCWE206C**	Scheme	2026
Type of Course	**Professional Elective Course**	Semester	II
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per Semester CI (L/T):LI(P):TW&SL	90(42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Type of Examination (PCC):	Theory- CIE +SEE	Exam Hours	03

Course outcome (Course Skill Set):

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

1. CO1 (L2): Explain the sources, characteristics and environmental impacts of industrial wastewaters and the regulatory framework governing their discharge.
2. CO2 (L2): Apply the principles of waste minimization, cleaner production, segregation and pre-treatment to reduce the volume and strength of industrial effluents.
3. CO3 (L3): Select and design appropriate physico-chemical, biological and advanced treatment processes for industrial wastewaters.
4. CO4 (L3): Analyze the manufacturing processes, effluent characteristics and treatment schemes of major water-polluting industries, including CETPs.
5. CO4 (L4): Conduct water and wastewater audits using water balance, flow measurement and benchmarking, and prepare audit reports.
6. CO6 (L5): Evaluate recycling, reuse, zero liquid discharge and resource-recovery options considering technical, economic and environmental sustainability.

Module-1

Industrial Wastewater: Characteristics and Regulations:

- Industrial water use and sources of wastewater: process, cooling, boiler blow-down, washing and domestic streams; types of industries and their pollution potential.
- Characteristics of industrial wastewater: pH, TSS, TDS, BOD, COD, oil and grease, nutrients, colour, heavy metals, toxic and refractory organics; biodegradability (BOD/COD ratio) and toxicity.
- Effects of industrial effluents on receiving water bodies, land, sewers and municipal wastewater treatment plants.
- Regulatory framework: Water (Prevention and Control of Pollution) Act 1974, Environment (Protection) Act 1986, role of CPCB and SPCBs, discharge standards, consent to establish and operate, categorisation of industries, online continuous effluent monitoring systems (OCEMS).

Linked COs: CO1, CO4. **Number of Hours: 08**

Module-2

Waste Minimisation and Pre-treatment:

- Flow measurement and wastewater sampling: grab and composite samples, sampling frequency, flow-proportional sampling, preservation and analysis.
- Waste minimisation and cleaner production: volume reduction, strength reduction, process modification, good housekeeping, raw material substitution, segregation of waste streams, by-product and material recovery.
- Water conservation in industries: recycling, cascading and reuse of process water; concept of specific water consumption.
- Pre-treatment: screening, oil and grease removal, equalisation (flow and quality), proportioning and neutralisation; design of equalisation and neutralisation units; discharge of industrial wastewater into municipal sewers.

Linked COs: CO2, CO3. **Number of Hours: 08**

Module-3

Treatment Technologies for Industrial Wastewater:

- Physico-chemical treatment: coagulation-flocculation, chemical precipitation of heavy metals, oxidation-reduction, adsorption, ion exchange; advanced oxidation processes (zonation, Fenton, UV/H2O2).
- Biological treatment: activated sludge and its modifications, SBR, MBBR, trickling filters; anaerobic treatment - anaerobic filters, UASB reactors and biogas recovery.
- Membrane and tertiary processes: MBR, ultrafiltration, Nano filtration, reverse osmosis; evaporation and crystallisation; concept and schemes of zero liquid discharge (ZLD).
- Sludge management: characteristics, thickening, dewatering and disposal of ETP sludge; handling of hazardous waste as per Hazardous and Other Wastes Rules, 2016.

Linked COs: CO3, CO6. **Number of Hours: 09**

Module-4

Industry-Specific Wastewater Management and CETPs:

- Manufacturing process, sources and characteristics of wastewater, waste minimisation opportunities and treatment flow sheets for: textile and dyeing, tannery, pulp and paper, sugar and distillery.
- Dairy and food processing, pharmaceutical, electroplating and metal finishing, petroleum refinery and fertiliser industries.
- Common Effluent Treatment Plants (CETPs): need, planning, design considerations, inlet standards, operation, financing and management models.
- Industrial clusters and eco-industrial parks: industrial symbiosis and resource recovery from industrial effluents.

Linked COs: CO3, CO4, CO6. **Number of Hours: 08**

Module-5

Water and Wastewater Audit:

- Water audit: need, objectives and types (preliminary and detailed); audit methodology - pre-audit activities, data collection, process mapping, flow measurement, water balance diagram, identification of losses; post-audit activities.
- Wastewater audit: characterisation of individual waste streams, pollution load inventory, mass balance, evaluation of ETP performance and compliance.
- Benchmarking of specific water consumption, identification of conservation and reuse opportunities, cost-benefit analysis and payback period of measures; preparation of the audit report.
- Environmental audit and management systems: Environmental Statement (Form V) under EP Rules, ISO 14001 and ISO 46001, water footprint and water neutrality; case studies on water audits and ZLD in industries.

Linked COs: CO2, CO5, CO6. **Number of Hours: 09**

Suggested Learning Resources:

Textbooks:

1. M. N. Rao and A. K. Dutta, Wastewater Treatment: Rational Methods of Design and Industrial Practices, 3rd Edition, Oxford & IBH Publishing.
2. N. L. Nemerow, Industrial Waste Treatment: Contemporary Practice and Vision for the Future, 1st Edition, Butterworth-Heinemann (Elsevier).
3. Metcalf & Eddy, Inc. (Tchobanoglous, Stensel, Tsuchihashi and Burton), Wastewater Engineering: Treatment and Resource Recovery, 5th Edition, McGraw-Hill Education.

Reference Books:

1. W. W. Eckenfelder Jr., *Industrial Water Pollution Control*, 3rd Edition, McGraw-Hill.
2. A. D. Patwardhan, *Industrial Wastewater Treatment*, 2nd Edition, PHI Learning.
3. F. Woodard, *Industrial Waste Treatment Handbook*, 2nd Edition, Butterworth-Heinemann.
4. L. K. Wang, Y. T. Hung, H. H. Lo and C. Yapijakis (Eds.), *Handbook of Industrial and Hazardous Wastes Treatment*, 2nd Edition, CRC Press.

Standards and Codes

1. The Water (Prevention and Control of Pollution) Act, 1974 and amendments, Government of India.
2. The Environment (Protection) Rules, 1986, Schedule I and VI - Industry-specific and General Standards for

Discharge of Environmental Pollutants.

3. Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016, MoEFCC.
4. Central Water Commission, General Guidelines for Water Audit and Water Conservation, Government of India.
5. ISO 14001:2015 Environmental *Management Systems* and ISO 46001:2019 Water Efficiency Management Systems.

Web links and Video Lectures (e-Resources) :

1. Online Repositories: NPTEL courses on Industrial Wastewater Treatment and Wastewater Treatment and Recycling (nptel.ac.in); CPCB publications, effluent standards and Comprehensive Industry Documents (cpcb.nic.in); CWC and Bureau of Water Use Efficiency guidelines on water audit.
2. Software Tools: MS Excel water balance and audit templates, GPS-X / BioWin (wastewater treatment process simulation), WAVE (Water Application Value Engine for RO/UF/IX design), EPANET (industrial water distribution network analysis).

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	**TW1-Industrial Effluent Characterisation:** Students shall collect or obtain effluent samples/data from an industry, determine key parameters (pH, TSS, TDS, BOD, COD, oil and grease, heavy metals) and compare them with CPCB discharge standards.	24
2	**TW2-Water Audit of a Facility:** Students shall carry out a water audit of the campus, hostel or an industrial unit, measure flows, prepare a	24

	water balance diagram, identify losses and recommend conservation and reuse measures with cost-benefit analysis.	
3	**TW3-ETP Design Proposal:** Students shall propose a treatment scheme for a given industry with process flow sheet, sizing of major units, sludge management plan and expected treated-water quality.	24
4	**TW4-Cleaner Production Assessment:** Students shall study the manufacturing process of an industry, prepare a pollution load inventory and suggest waste minimisation, segregation and resource-recovery options.	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	**SL-1: Case Study on CETP / ZLD:** Students shall study a real CETP or zero liquid discharge installation and summarise the treatment scheme, performance, economics, challenges and lessons learned.	24
2	**SL-2: Regulatory Review:** Students shall review the effluent discharge standards, consent mechanism and compliance requirements applicable to a chosen industrial sector.	24
3	**SL-3: Emerging Technologies Review:** Students shall prepare a comparative note on emerging treatment and recovery technologies (AOPs, MBR, forward osmosis, electrocoagulation) and their suitability for industrial effluents.	24

Sample rubrics for TW activities:

Criterion	**Excellent 4**	**Good 3**	**Satisfactory 2**	**Needs Improvement 1**
Understanding of wastewater/audit concept	Correctly identifies and explains the issue with strong technical clarity.	Identifies the issue well with minor gaps.	Basic identification with limited explanation.	Incorrect or incomplete understanding.
Technical accuracy	Methods and observations are technically sound.	Minor technical errors.	Several conceptual gaps.	Major technical errors.
Regulatory and sustainability consideration	Clearly integrates discharge standards, reuse and sustainability thinking.	Adequate regulatory and sustainability linkage.	Limited regulatory or sustainability reference.	No regulatory or sustainability linkage.
Presentation and organization	Professional format, clear diagrams/tables, logical flow.	Well organized with minor formatting issues.	Acceptable but uneven presentation.	Poorly organized or incomplete.
Practical relevance	Strong real-world applicability and justified recommendations.	Good practical relevance.	Limited application.	No meaningful practical connection.

Rubrics for SL Activities:

Criterion	**Excellent 4**	**Good 3**	**Satisfactory 2**	**Needs Improvement 1**
Quality of literature/case review	Uses relevant and credible sources with strong synthesis.	Good sources with adequate synthesis.	Limited sources, basic summary.	Weak or missing sources.
Technical content	Accurate, complete, and conceptually strong.	Mostly accurate with minor omissions.	Partial coverage of content.	Inaccurate or incomplete content.
Independent learning	Shows clear self-learning and critical thinking.	Some evidence of independent effort.	Limited independent analysis.	Minimal effort or copied content.
Sustainability and reuse focus	Strong emphasis on waste minimisation, recycling and reuse.	Moderate sustainability linkage.	Weak sustainability linkage.	No sustainability focus.
Communication quality	Clear, concise, and professionally presented.	Mostly clear with minor issues.	Understandable but inconsistent.	Poorly written or disorganized.

GEOSPATIAL TECHNOLOGY			
Course Code	**1MCWE206D**	Scheme	2026
Type of Course	**Professional Elective Course**	Semester	II
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per Semester CI (L/T):LI(P):TW&SL	90(42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Type of Examination (PCC):	Theory- CIE +SEE	Exam Hours	03

Course outcome (Course Skill Set):

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

1. CO1 (L2): Explain the fundamentals of geodesy, datums, coordinate systems, map projections and GNSS-based positioning.
2. CO2 (L2): Interpret remote sensing data using the principles of electromagnetic radiation, sensor platforms and image characteristics.
3. CO3 (L3): Apply digital image processing and classification techniques to extract thematic information from satellite imagery.
4. CO4 (L4): Develop GIS databases and perform spatial analysis using vector and raster data models.
5. CO5 (L4): Analyze terrain, hydrological and land use data using DEM, remote sensing and GIS for water resources and infrastructure applications.
6. CO6 (L5): Integrate emerging geospatial tools such as UAV photogrammetry, LiDAR, WebGIS and cloud platforms for planning and decision-making.

Module-1

Remote Sensing:

- Remote Sensing Basic Principles: Introduction, Electromagnetic Remote Sensing Process, Physics of Radiant
- Energy: Nature of Electromagnetic Radiation, Electromagnetic Spectrum ; Energy Source and its Characteristics, Atmospheric Interactions with Electromagnetic Radiation: Atmospheric properties, Absorption of Ozone, Atmospheric effects on Spectral Response Patterns; Energy interactions with Earth's surface materials: Spectral Reflectance Curves; Cossine Law.
- Remote Sensing Platforms and Sensors: Satellite System Parameters, Sensor Parameter: Spatial Resolution,
- Spectral Resolution, Radiometric Resolution; Imaging Sensor Systems: Multispectral Imaging Sensor System, Thermal Sensing System, Microwave Imaging Systems; Earth Resources Satellites: Landsat Satellite
- Programme, SPOT Satellite, Indian Remote Sensing Satellite (IRS);
- Meteorological Satellites: NOAA Satellite, GOES Satellite.

Linked COs: CO1, CO6. **Number of Hours: 08**

Module-2

Visual Image Interpretation: Introduction

- Digital Image Processing: Introduction, Basic Character of Digital Image, Pre-processing: Geometric
- Correction Methods, Radiometric Geometric Correction, Atmospheric Geometric Correction; Image
- Enhancement Techniques: Contrast Enhancement; Spatial Filtering Techniques: Low Pass Filters, High Pass Filters, Filtering for Edge Enhancement; Image Transformations NDVI Transformation, PCA Transformation; Image Classification: Supervised Classification, Training Dataset, Unsupervised Classification.

Linked COs: CO2, CO5. **Number of Hours: 08**

Module-3

Geographical Information System:

- Introduction to GIS: Introduction to GIS History of GIS, Early developments in GIS, Applications of GIS, Spatial Data Input and Editing: Primary Data, Secondary Data, and Data Editing.
- Introduction: Maps and Map Scale, Map Scale, Type of Maps, Map and Glob. Geo-referencing and Projection: Understanding Earth, Coordinate System, Map Projection, Transformation,
- Geo-referencing.

Linked COs: CO2, CO3. **Number of Hours: 09**

Module-4

- Global Positioning System (GPS): Introduction.
- Spatial Database Management Systems: Introduction, Data Storage, Database Structure Models, Database
- Management system, Entity Relationship Model, Normalization.
- Data Models and Data Structures: Introduction, GIS Data Model, Vector Data Structure, Raster Data structure, Geodatabase and Metadata.

Linked COs: CO4, CO5. **Number of Hours: 08**

Module-5

- Spatial Analysis: Introduction to spatial analysis, Vector Operations and Analysis, Network Analysis, Raster Data and Spatial Analysis.
- Interpolation: Introduction to Interpolation, Global Methods of Interpolation, Local Methods of Interpolation.
- Web GIS: Introduction, Web GIS, OGC & Web Services.

Linked COs: CO5, CO6. **Number of Hours: 09**

Suggested Learning Resources:

Textbooks:

1. M. Anji Reddy, _Remote Sensing and Geographical Information Systems‘4th Edition, BS Publications.
2. Kang-tsung Chang, Introduction to Geographic Information Systems, 9th Edition, McGraw Hill Education.
3. Basudeb Bhatta, Remote Sensing and GIS, 3rd Edition, Oxford University Press.

Reference Books:

1. J. R. Jensen, *Introductory Digital Image Processing: A Remote Sensing Perspective*, 4th Edition, Pearson.
2. P. A. Burrough, R. A. McDonnell and C. D. Lloyd, *Principles of Geographical Information Systems*, 3rd Edition, Oxford University Press.
3. B. Hofmann-Wellenhof, H. Lichtenegger and E. Wasle, *GNSS - Global Navigation Satellite Systems: GPS, GLONASS, Galileo and More*, 1st Edition, Springer.

Standards and Guidelines

1. National Geospatial Policy 2022, *Department of Science and Technology, Government of India*.
2. Guidelines for Acquiring and Producing Geospatial Data and Geospatial Data Services including Maps, *Department of Science and Technology, Government of India, 2021*.
3. ISO 19100 series, *Geographic Information/Geomatics Standards*, International Organization for Standardization.
4. Open Geospatial Consortium (OGC) standards: WMS, WFS, WCS and GeoPackage, latest versions.

Web links and Video Lectures (e-Resources) :

1. Online Repositories: NPTEL courses on "Remote Sensing and GIS" and "Geographic Information Systems"; IIRS-ISRO e-learning and outreach programmes (iirs.gov.in); NRSC Bhuvan geoportal (bhuvan.nrsc.gov.in); USGS Earth Explorer (earthexplorer.usgs.gov); Copernicus Data Space Ecosystem (dataspace.copernicus.eu).
2. Software Tools: QGIS and GRASS GIS (open-source GIS and spatial analysis), Google Earth Engine (cloud-based satellite image processing), ESA SNAP (Sentinel data processing), ArcGIS Pro, and GNSS post-processing software such as RTKLIB.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching

- Role Play

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	**TW1-GNSS Field Survey and Mapping:** Students shall collect GNSS coordinates of selected campus or field features, process and import the data into GIS, and prepare a georeferenced thematic map with attribute information.	24
2	**TW2-Land Use/Land Cover Classification:** Students shall download Landsat/Sentinel-2 imagery of a study area, perform pre-processing and supervised classification, and report the accuracy assessment using an error matrix and Kappa statistic.	24
3	**TW3-Watershed Delineation and Morphometric Analysis:** Students shall delineate a watershed from a DEM, extract the drainage network, compute linear, areal and relief morphometric parameters, and interpret the hydrological characteristics.	24
4	**TW4-GIS-based Site Suitability Analysis:** Students shall perform multi-criteria (AHP-based) overlay analysis to identify suitable zones for a water resources or infrastructure application such as groundwater recharge structures or rainwater harvesting sites.	24

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	**SL-1: Earth Observation Mission Review:** Students shall review a recent Indian or global earth observation mission (e.g., NISAR, Cartosat-3, EOS series or Sentinel), summarizing sensor characteristics, data products and engineering applications.	24
2	**SL2-Online Course on Geospatial Technology:** Students shall complete a relevant NPTEL/IIRS-ISRO online module on remote sensing or GIS and submit a summary report with key learnings and a sample hands-on output.	24

3	**SL3-Case Study on Geospatial Application:** Students shall study a published case of geospatial technology applied to flood mapping, landslide susceptibility, drought monitoring or urban growth, and summarize the data used, methodology, results and lessons learned.	24

Sample rubrics for TW activities:

Criterion	**Excellent 4**	**Good 3**	**Satisfactory 2**	**Needs Improvement 1**
Understanding of geospatial concepts	Correctly explains concepts, methods and workflow with strong technical clarity.	Explains concepts well with minor gaps.	Basic understanding with limited explanation.	Incorrect or incomplete understanding.
Technical accuracy	Data processing, analysis and results are technically sound.	Minor technical errors.	Several conceptual or processing errors.	Major technical errors.
Data handling and tool usage	Selects appropriate datasets and tools; processes data correctly and efficiently.	Appropriate data and tools with minor processing issues.	Limited data handling with some errors.	Inappropriate data or incorrect tool usage.
Presentation and cartographic quality	Professional maps with legend, scale, north arrow and grid; clear tables and logical flow.	Well organized with minor layout or formatting issues.	Acceptable but uneven presentation.	Poorly organized or incomplete.
Practical relevance	Strong real-world applicability and justified recommendations.	Good practical relevance.	Limited application.	No meaningful practical connection.

Rubrics for SL Activities:

Criterion	**Excellent 4**	**Good 3**	**Satisfactory 2**	**Needs Improvement 1**
Quality of literature/case review	Uses relevant and credible sources with strong synthesis.	Good sources with adequate synthesis.	Limited sources, basic summary.	Weak or missing sources.
Technical content	Accurate, complete, and conceptually strong.	Mostly accurate with minor omissions.	Partial coverage of content.	Inaccurate or incomplete content.
Independent learning	Shows clear self-learning and critical thinking.	Some evidence of independent effort.	Limited independent analysis.	Minimal effort or copied content.
Application focus	Strong linkage to civil and water engineering applications of geospatial technology.	Moderate application linkage.	Weak application linkage.	No application focus.
Communication quality	Clear, concise, and professionally presented.	Mostly clear with minor issues.	Understandable but inconsistent.	Poorly written or disorganized.

LIFE CYCLE ASSESSMENT FOR ENVIRONMENTAL SYSTEMS			
Course Code	**1MCWE206E**	Scheme	2026
Type of Course	**Professional Elective Course**	Semester	II
Teaching Hours/Week (L:T:P)	42(3:0:0)	CIE Marks	50
Total Hours of Pedagogy per Semester CI (L/T):LI(P):TW&SL	90(42:0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Type of Examination (PCC):	Theory- CIE +SEE	Exam Hours	03

Course outcome (Course Skill Set):

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

- CO1 (L2): Explain the principles, framework, and ISO standards of life cycle assessment (LCA) and life cycle thinking for environmental systems.
- CO2 (L3): Define goal and scope, functional units, and system boundaries, and compile life cycle inventories for environmental engineering processes.
- CO3 (L3): Apply life cycle impact assessment methods to quantify impacts such as climate change, acidification, eutrophication, and toxicity.
- CO4 (L3): Interpret LCA results using contribution, sensitivity, and uncertainty analyses to support environmental decision-making.
- CO5 (L4): Use LCA software tools and databases to model water, wastewater, solid waste, and energy systems.
- CO6 (L5): Evaluate environmental systems using carbon and water footprints, life cycle costing, and circular economy approaches for sustainable decisions.

Module-1

Introduction to Life Cycle Thinking and LCA Framework:

- Sustainability and life cycle thinking; cradle-to-grave, cradle-to-gate, and cradle-to-cradle concepts; evolution and applications of LCA in environmental engineering.
- LCA framework and phases as per ISO 14040 and ISO 14044: goal and scope definition, inventory analysis, impact assessment, and interpretation.
- Types of LCA: attributional and consequential LCA, screening/streamlined LCA, process-based, environmentally extended input-output, and hybrid LCA.
- Related environmental tools: environmental impact assessment, material flow analysis, eco-design, eco-labels, and environmental product declarations (EPDs).

Linked COs: CO1, CO2. **Number of Hours: 08**

Module-2

Goal and Scope Definition and Life Cycle Inventory:

- Goal and scope definition: intended application, functional unit, reference flow, system boundaries, cut-off criteria, and data quality requirements.
- Life cycle inventory (LCI): process flow diagrams, unit processes, foreground and background data, data collection, and mass and energy balances.
- Allocation procedures for multi-output processes and recycling: physical and economic allocation, system expansion, and substitution.
- LCI databases (ecoinvent, USLCI, ELCD), data validation, handling data gaps, and regionalisation of data for Indian conditions.

Linked COs: CO2, CO5. **Number of Hours: 08**

Module-3

Life Cycle Impact Assessment:

- LCIA elements: selection of impact categories, classification, characterization, normalization, grouping, and weighting.
- Midpoint and endpoint approaches; LCIA methods: CML, ReCiPe, TRACI, IMPACT World+, and Environmental Footprint (EF).
- Impact categories: global warming, ozone depletion, acidification, eutrophication, photochemical ozone formation, human and eco-toxicity (USEtox), resource depletion, land use, and water use.
- Numerical problems on characterization and calculation of impact indicator results for simple product

and process systems.

Linked COs: CO3, CO4. **Number of Hours: 09**

Module-4

Interpretation, Uncertainty, and LCA Tools:

- Life cycle interpretation: identification of significant issues, completeness, consistency, and contribution (hotspot) analysis.
- Sensitivity, scenario, and uncertainty analysis (Monte Carlo simulation); data quality indicators and the pedigree matrix approach.
- Critical review, reporting requirements, comparative assertions, and communication of LCA results.
- LCA software tools: open LCA, SimaPro, and Sphera LCA for Experts (GaBi); modelling workflow and demonstration.

Linked COs: CO4, CO5. **Number of Hours: 08**

Module-5

LCA Applications in Environmental Systems and Case Studies:

- LCA of water supply and treatment systems, desalination, wastewater treatment, and sludge management options.
- LCA of municipal solid waste management: landfilling, composting, anaerobic digestion, incineration, and recycling.
- Carbon footprint (ISO 14067), water footprint (ISO 14046), life cycle costing, social LCA, and circular economy indicators.
- Case studies on renewable energy systems, air pollution control, construction materials, and environmental infrastructure.

Linked COs: CO3, CO5, CO6. **Number of Hours: 09**

Suggested Learning Resources:

Textbooks:

1. Michael Z. Hauschild, Ralph K. Rosenbaum, and Stig Irving Olsen (Eds.), Life Cycle Assessment: Theory and Practice, 1st Edition, Springer, 2018.
2. Mary Ann Curran (Ed.), Life Cycle Assessment Handbook: A Guide for Environmentally Sustainable Products, 1st Edition, Wiley-Scrivener, 2012.
3. Walter Klöpffer and Birgit Grahl, Life Cycle Assessment (LCA): A Guide to Best Practice, 1st Edition, Wiley-VCH, 2014.

Reference Books:

1. Henrikke Baumann and Anne-Marie Tillman, *The Hitch Hiker's Guide to LCA: An Orientation in Life Cycle Assessment Methodology and Application*, 1st Edition, Studentlitteratur, 2004.
2. Jeroen B. Guinée (Ed.), *Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards*, Kluwer Academic Publishers, 2002.
3. H. Scott Matthews, Chris T. Hendrickson, and Deanna H. Matthews, *Life Cycle Assessment: Quantitative Approaches for Decisions That Matter*, Open-access textbook, 2014.
4. Mary Ann Curran, *Environmental Life Cycle Assessment*, 1st Edition, McGraw-Hill, 1996.

Standards and Codes

1. ISO 14040:2006, *Environmental Management - Life Cycle Assessment - Principles and Framework*.
2. ISO 14044:2006, *Environmental Management - Life Cycle Assessment - Requirements and Guidelines*.
3. ISO 14067:2018, *Greenhouse Gases - Carbon Footprint of Products - Requirements and Guidelines for Quantification*.
4. ISO 14046:2014, Environmental Management - Water Footprint - Principles, Requirements and Guidelines; and JRC ILCD Handbook, European Commission, 2010.

WeblinksandVideoLectures(e-Resources) :

1. Online Repositories: NPTEL course "Sustainable Engineering Concepts and Life Cycle Analysis" (Prof. Brajesh Kumar Dubey, IIT Kharagpur) - https://onlinecourses.nptel.ac.in/noc26_ce44/preview; UNEP Life Cycle Initiative resources; open-access LCA textbook - https://www.lcatextbook.com.
2. Software Tools: openLCA (free, open-source LCA software - https://www.openlca.org), SimaPro, Sphera LCA

for Experts (GaBi), and LCI databases such as ecoinvent, USLCI, and the Federal LCA Commons.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	**TW1-Goal and Scope Definition:** Students shall define the goal, scope, functional unit, and system boundary for a selected environmental system (e.g., a water treatment plant or a solid waste facility) and draw its process flow diagram.	24
2	**TW2-Life Cycle Inventory Compilation:** Students shall compile foreground and background inventory data for a chosen process, perform mass and energy balances, and apply a suitable allocation procedure.	24
3	**TW3-LCA Modelling Using Software:** Students shall model the selected system in open LCA (or equivalent), carry out impact assessment using a standard LCIA method, and identify environmental hotspots.	24
	TW4-Comparative LCA and Interpretation: Students shall compare two alternatives (e.g., landfilling vs. composting, or centralized vs. decentralized wastewater treatment), perform sensitivity analysis, and recommend the preferred option.	24

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	**SL-1: Review of a Published LCA Study:** Students shall critically review a published LCA study on an environmental system and summarize its goal, scope, assumptions, results, and limitations.	24
2	**SL2-LCIA Method Comparison**: Students shall compare two LCIA methods (e.g., ReCiPe and CML) with respect to impact categories, characterization models, and applicability.	24
3	**SL3-Carbon and Water Footprint Review:** Students shall prepare a note on carbon and water footprint standards and estimate the footprint of a common product or service using published data.	24

Sample rubrics for TW activities:

Criterion	**Excellent 4**	**Good 3**	**Satisfactory 2**	**Needs Improvement 1**
Understanding of LCA concepts/methodology	Correctly defines and explains LCA concepts with strong technical clarity.	Explains concepts well with minor gaps.	Basic identification with limited explanation.	Incorrect or incomplete understanding.
Technical accuracy	Inventory data, calculations, and modelling are technically sound.	Minor technical errors.	Several conceptual gaps.	Major technical errors.
Environmental interpretation	Clearly interprets impacts, hotspots, and sustainability implications.	Adequate interpretation of results.	Limited interpretation of results.	No meaningful interpretation.
Presentation and organization	Professional format, clear diagrams/tables, logical flow.	Well organized with minor formatting issues.	Acceptable but uneven presentation.	Poorly organized or incomplete.
Practical relevance	Strong real-world applicability and justified recommendations.	Good practical relevance.	Limited application.	No meaningful practical connection.

Rubrics for SL Activities:

Criterion	**Excellent 4**	**Good 3**	**Satisfactory 2**	**Needs Improvement 1**
Quality of literature/case review	Uses relevant and credible sources with strong synthesis.	Good sources with adequate synthesis.	Limited sources, basic summary.	Weak or missing sources.
Technical content	Accurate, complete, and conceptually strong.	Mostly accurate with minor omissions.	Partial coverage of content.	Inaccurate or incomplete content.

Criterion	Excellent 4	Good 3	Satisfactory 2	Needs Improvement 1
Independent learning	Shows clear self-learning and critical thinking.	Some evidence of independent effort.	Limited independent analysis.	Minimal effort or copied content.
Sustainability focus	Strong emphasis on environmental impacts and sustainable decisions.	Moderate sustainability linkage.	Weak sustainability linkage.	No sustainability focus.
Communication quality	Clear, concise, and professionally presented.	Mostly clear with minor issues.	Understandable but inconsistent.	Poorly written or disorganized.

HYDRO-SOIL ENGINEERING LAB			
Course Code	**1MCWEL207**	Scheme	2026
Type of course	Professional Core Course Lab	Semester	II
Teaching Hours/Week (L:T:P)	2(0: 0: 2)	CIE Marks	50
Total Hours of Pedagogy L:T:P:SL:TW	30(0: 0:28:2)	SEE Marks	50
Credits	1	Total Marks	100
Type of Examination	**Practical**	Exam Hours	3

Course outcome (Course Skill Set)

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

1. CO1 (L3): Conduct standard laboratory tests to determine the hydraulic, consolidation, and strength properties of soils as per relevant codes of practice.
2. CO2 (L4): Interpret test data on permeability, consolidation, pore water pressure, and shear strength of soils under different drainage and saturation conditions.
3. CO3 (L4): Analyze soil-water interaction phenomena such as seepage, infiltration, suction, piping, and internal erosion in soil systems.
4. CO4 (L5): Evaluate the suitability of soils and filter materials for earthen embankments, hydraulic structures, canal linings, and drainage systems.
5. CO5 (L6): Develop experimental and numerical solutions for hydro-soil engineering problems and prepare professional technical reports.

Note:

1. The laboratory syllabus consists of PART-A and PART-B. While PART-A has 6-8 conventional experiments, PART-B has 6 typical open-ended experiments. The maximum marks for the laboratory course are 100.
2. Both PART-A and PART-B are considered for CIE and SEE.
3. Students have answer 1(one) question from PART-A and 1(one) question from PART-B.
   a. The questions set for SEE shall be from among the experiments under PART-A. It is evaluated for **80 marks** out of the maximum 100 marks.
   b. The open-ended question set for SEE shall be any other open-ended question and not selected from the experiments under PART-A. It shall be evaluated for **20 marks.**

For Continuous Internal Evaluation (CIE) during the semester, classwork shall typically include open-ended questions from **Part-B**, along with other similar questions designed to enhance the students' skills.

PART – A

FIXED EXPERIMENTS

1. Determination of infiltration rate using Double ring infiltrometer.
2. Determination of flow in open stream.
3. Determination of sediment yield of the watershed.
4. Determination of ET using actual weather data and comparison with atmometer
5. Determination of sub-surface formation using electrical resistivity method.
6. Measurement of Mean Emission Rate of Emitting tube
7. Determination of Tensile Strength & Elongation of Lateral
8. Determination of Melt Flow Index

PART – B

OPEN ENDED EXPERIMENTS

1) Open-ended experiments are a type of laboratory activity where the outcome is not predetermined and students are given the freedom to explore, design, and conduct the experiment based on the problem statements as per the concepts defined by the course coordinator. It encourages creativity, critical thinking, and inquiry-based learning.

1. Carbon Black Dispersion test. & Carbon black content test
2. Resistance of emitting tube to hydrostatic pressure at ambient/ elevated temperature
3. Reversion Test .
4. Resistance to Pull outs of Joints between fitting and emitting tube.

Textbooks:

1. Arora, K. R., **Soil Mechanics and Foundation Engineering**, Standard Publishers Distributors.
2. Das, B. M., **Advanced Soil Mechanics**, CRC Press.
3. Cedergren, H. R., **Seepage, Drainage, and Flow Nets**, John Wiley & Sons.
4. Fredlund, D. G., Rahardjo, H., and Fredlund, M. D., **Unsaturated Soil Mechanics in Engineering Practice**, John Wiley & Sons.

Reference books / Manuals:

1. Head, K. H., Manual of Soil Laboratory Testing, Vols. 1-3, Whittles Publishing / CRC Press.
2. Harr, M. E., Groundwater and Seepage, Dover Publications.
3. Subramanya, K., Engineering Hydrology, McGraw-Hill Education.
4. IS 2720 (relevant parts) Methods of Test for Soils, Bureau of Indian Standards; relevant ASTM standards (D5084, D6836, D4647) and laboratory manuals.

Equipment / Software tools:

1. Constant head and falling head permeameters, odometer, and triaxle apparatus with pore pressure and volume change measurement.
2. Sand tank / Hele-Shaw seepage model, double-ring infiltrometer, pressure plate apparatus / torsiometers, and pinhole test apparatus.
3. GeoStudio SEEP/W, PLAXIS, or equivalent for seepage and coupled flow-deformation analysis.
4. Excel, MATLAB, or Python for data reduction, curve fitting, tabulation, and graphs.
5. Any equivalent equipment or software approved by the department.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for a pass in the course.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject /course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation (CIE):

For the Professional Core Course Laboratory, the maximum marks prescribed are 100. Out of these, 50 marks are allotted for Continuous Internal Evaluation (CIE) and 100 marks for the Semester End Examination (SEE). The SEE marks obtained out of 100 shall be proportionately scaled down to 50 marks. The final result shall be declared based on the aggregate of the CIE marks (50) and the scaled-down SEE marks (50), totalling 100 marks."

Out of 50 marks, 40 marks shall be assigned for assessment of regular laboratory PART -A classwork, and 10 marks for Part – B. (Table 1)

Out of 40 marks, 25 marks shall be based on the regular classwork and allotment of marks shall be as per rubrics listed in Table 1.

The remaining 15 marks shall be based on the practical test conducted by two Internal examiners appointed by the HoD. The allotment of marks shall be as per the rubrics defined for the practical test as indicated in the Table 1.

The open-ended question set for CIE shall be any other open-ended question and not selected from the experiments under PART-A. It shall be evaluated for 10 marks. The allotment of marks shall be as per rubrics listed in Table 2.

Table–1Distributionofmarkscorrespondingtolaboratorycomponent

Component	Description	Marks
Allotment of marks for regular class work		
Ability in Conducting Experiments	Initiative, skill, safety practices, teamwork, and independent handling of equipment using regular lab sessions.	10 marks
Laboratory Record/ Journal	Regular and neat maintenance of lab record, accuracy of results, and timely submission.	15marks
	Subtotal	**25**
Allotment of marks for CIE practical test		

Laboratory Test/ Experiment Performance	Ability to setup apparatus, follow procedure, take Observations ,and obtain correct results in the test experiment.	5marks
Viva-Voce	Understanding of theory, concepts, and experimental procedure; ability to explain results and answer related questions.	10marks
	Subtotal	**15**
	Total	**40**

Table2DistributionofmarkscorrespondingtoPART-Bofthelaboratorycomponent EvaluationRubricsforcontinuousinternalevaluationCIE).Maximummarks:10

Criteria and Guiding factors	**Students 'Level and Rubrics Excellent :E, Good:G, Fair:F Needs Improvements : NI**			
	E	**G**	**F**	**NI**
(1) Problem Understanding **Criteria:** Is the problem understood correctly and framed appropriately? (i)Clarity in interpreting the given problem. (ii)Identification of relevant concept sand constraints. (iii)Ability to rephrase or model the problem logically.	2.0	1.5	1.0	0.5
(2) Conceptual Knowledge **Criteria**: Are the chosen methods or concepts valid for this type of problem? (i) Application of appropriate theories, principles, or laws. (ii) Integration of multiple concepts where necessary. (iii)Accuracy in stating relevant equations or models.	2.0	1.5	1.0	0.5
(3) Approach and Strategy **Criteria**: Is the approach well thought out and methodical? (i) Logical structure and progression. (ii) Use of diagrams, sketches, or flow c harts if applicable. (iii)Identification of assumptions and boundary conditions.	2.0	1.5	1.0	0.5
(4) Execution and Accuracy **Criteria**: Are the calculations correct? Is the final solution reasonable? (i) Correct application of formulas/methods. (ii) Accuracy of calculations or simulations(if any). (iii)Unit consistency and result verification.	2.0	1.5	1.0	0.5
(5) Innovation or Depth **Criteria**: Has the student shown original thinking or alternative methods? (i)Novel or efficient solutions. (ii)Consideration of alternate approaches. (iii)Interdisciplinary integration or practical extensions.	1	0.75	0.5	0.25
(6) Presentation and Clarity **Criteria**: Is the answer easy to follow and professionally written? (i) Organization and neatness. (ii) Clarity of explanation, labelling, and steps. (iii) Use of proper technical terminology.	1	0.75	0.5	0.25
Total	10	7.5	5.0	2.5

Note:

(i) The marks shown for Excellent, Good, Fair, Needs Improvement are indicative. The evaluator may also assign intermediate scores depending on the quality of work.

(ii) If the total score results in a fraction, it should be rounded off to then Ext higher integer.

(iii) The listed criteria are guidelines; evaluators may also consider other authentic dimensions (e.g., depth of insight, critical thinking, and practical awareness, recognition of limitations, or justified compromises.

(iv) To award the full10 marks in the excellent category, the student must demonstrate reasonably good performanceacrossallsixcriteria;otherwise,proportionallylowermarksmaybegiven.