COURSES

Program: Water Resources Engineering

Semester I

S. N.	Subjects	Credits
1.	**Core Courses** Advanced Hydraulics	4
2.	Hydrologic Analysis	4
3.	Simulation Laboratory	4
4.	System Mathematics	4
5.	**Elective Courses** Sedimentation Engineering	4
	Minimum Required Credit	**20**

Semester II

S.N.	Subjects	Credits
1.	**Core Courses** Hydraulic Structure	4
2	Water Induced Hazard	4
3.	**Elective Courses** River Engineering	4
4.	Time Series Analysis	4
5.	GIS and Remote Sensing	4
6.	Water Resources Planning & Management	4
	Minimum Required Credit	**20**

Semester III

S.N.	Subjects	Credits
1.	**Core Courses** Group Project	4
2.	**Elective Courses** Hydropower Engineering	4
3.	Irrigation and Drainage Engineering	4
	Minimum Required Credit	**8**

Semester IV

S.N.	Subjects	Credits
1.	Dissertation	16
	Total	**16**

Subject: Advanced Hydraulics (Core) 4 Credits

Rationale:

To develop for the student (1) knowledge of advanced topics in fluid mechanics; (2) insight into essential principles that govern the flow of water in pipes, conduits and open channels; (3) analytical skills needed to describe and predict flow behavior in conveyance systems using modern computational tools; and (4) ability to effectively apply these principles and skills to the analysis and hydraulic design of water resource engineering structures..

Catalogue Description:

Stream function; potential flow; viscous flow; boundary layer theory; turbulence; flow resistance; unsteady closed conduit flow; open channel flow; water surface profiles; flow through culverts; gravity wave; positive and negative surges; St. Venant equations; Characteristics; surface water transport processes.

Prerequisites: None

Course Outline:

1. Introduction

Recapitulation of basic concepts of open channel hydraulics, Types of Flow, Flow profiles-Characteristics and Types.

2. Unsteady Open Channel Flow

Derivation of St. Venants Equations: Using Energy approach and momentum approach.

3. Gradually Varied Steady Flow

Derivation of Gradually Varied Steady Flow Using St. Venants Equations, Energy approach, Momentum approach, Solution of Gradually Varied Steady Flow Equation: Direct Integration methods- Bresse’s Function, Bakhmeteff Varied Flow function, Ven Te Chow’s Analysis; Graphically Methods-Grimm’s Method, Escoffer Method, Ezra Method; Numerical Integration Methods- Direct Step Method, Standard Step Method, Newton’s Iteration Method; Computer Program- HECRAS, SFAM.

4. Solution of Gradually Varied Unsteady Flow Equations:

Method of Characteristics: characteristic grid method, specified interval method; Explicit finite difference scheme: Unstable scheme, diffusive scheme, Maccormack scheme; Implicit finite difference technique: Amein 4 point implicit scheme; Computer Programs- HECRAS 3.0.

5. Unsteady Flow in Closed Conduits

Introduction; Effects and control of Transient Cavitation; Cavitation Description; Transient Analysis; Results and Discussions; Methods for controlling Hydraulic Transients

6. Surge tanks

Function and behavior; classification; hydraulic design considerations; methods and equations for surge analysis; stability against resonance; downstream surge tanks; design of restricted orifice and differential surge tanks; physical models.

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Subject: Hydrologic Analysis (Core) 4 Credits

Rationale:

Hydrological events such as flood and droughts have significant impact on water resources development and a corresponding responsibility rests upon the hydrologist to provide the best information that current knowledge and available data will permit. It gives a practical approach to the various facets of the subject and emphasizes the application of hydrological knowledge to solving engineering problems.

Catalogue Description:

Introduction, Modeling of the Infiltration Component of the Rainfall-Runoff Process, Linear Black-Box Models, Linear Conceptual Models, Channel Flow Routing, Catchment Routing, Frequency Analysis, Analysis Techniques for Low-Flow Hydrology (Drought).

Prerequisites: None

Course Outline:

1. Introduction (2 hrs)

Physical Approach, Systems Approach, Problems and Models in Hydrology

2. Modeling of the Infiltration Component of the Rainfall-Runoff Process (5 hrs)

Introduction: Watershed Models, Infiltration Component, The Infiltration Process: Definitions, Infiltration-The Natural Soils, Rainfall Intensity, Existing Infiltration Models: Empirical Equations (Kostyakov, Horton, Holton equations), The Green and Ampt Equation, The Need for a Simple Model, Mein and Larson Infiltration Model: Prediction of the Infiltration Volume Prior to Runoff, The Capillary Potential at the Wetting Front, Prediction of the Infiltration Capacity After Runoff Begins.

3. Watershed Conceptual Models (4 hrs)

Crawford Model: Elements of Crawford Model, Building a Crawford Model, Tank Model: Structure of Tank Model, Behavior of Tank Model, Building a Tank Model.

4. Linear Black-Box Models (8 hrs)

Types of Catchment Response, The Rational Method: Methodology, Effect of Catchment Shape, The Unit Hydrograph Method: Mathematical Representation., Change in Unit Hydrograph Duration, Convolution and Composite Hydrographs, Unit Hydrographs from Complex Storms, The Collins Method, Method of Least Squares.

5. Linear Conceptual Models (10 hrs)

General Hydrologic System Model, Linear System in Continuous Time, Response Function of Linear Systems: Impulse Response Function, Step Response Function, Pulse Response Function, The Nash Model.

6. Channel Flow Routing (12 hrs)

Convex Method, Muskingum Method, Kinematic Waves: Kinematic Wave Equation, Discretization of Kinematic Wave Equation, Order of Accuracy of Numerical Scheme, Kinematic Wave Celerity, Applicability, Diffusion Waves: Diffusion Wave Equation, Applicability, Muskingum-Cunge Method, Introduction to Dynamic Waves.

7. Catchment Routing (8 hrs)

Time Area Method, Clark Unit Hydrograph, Cascade of Linear Reservoirs, Catchment Routing with Kinematic Waves, Catchment Routing with Diffusion Waves, Assessment of Catchment-Routing Techniques.

8. .Catchment Modeling (2 hrs)

Introduction to HEC-HMS Model, Performing Simulations and Example Application.

Subject: Simulation Laboratory (Core) 4 Credits

Rationale:

Catalogue Description:

Prerequisites: None

Course Outline:

1. **Concepts of simulation**
   Steps in simulation study, Advantages of simulation, Limitation, Areas of applications

2. **Least Square technique and its application in Water resources engineering**
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3. **Regression models and its application in Water resources engineering**

4. **Updating procedures**

5. **Recursion of mean, variance and least square estimation**

6. **Numerical methods**
   Finite difference scheme, Derivation of Numerical diffusion, Stability of scheme, Jameson artificial viscosity for smoothening, Leap frog Scheme, Monte Carlo Simulation

7. **Computer Programming**
   One dimensional and Two dimensional arrays, Sub programs, Source codes , Steady and unsteady infiltration models, Application of least square technique, Regression models, Recursive schemes, Kinematic wave Catchment routing, Diffusion wave catchment routing, Muskingum Cunge routing method, Monte Carlo Simulation.

8. **Graphics**
   Drawing lines and text, colours etc , Application in models, Design of dialog box.

Subject: Sedimentation Engineering (Elective) 4 Credits

Rationale:

To develop (1) a sound foundation in the mechanics of noncohesive sediment transport in rivers; (2) insight into the application of analytical and semi-theoritical theories and equations for the prediction of transport rates; (3) knowledge of the methods of sediment sampling and analysis; (4) understanding of sediment deposition in reservoirs and methods to preserve the storage capacity.

Catalogue Description:
Sediment size distribution; critical shear stress; incipient motion; bed-forms; flow regimes; mobile boundary channels, flow resistance; sediment non-uniformity; stream power; bed load; suspended load; total bed material load; non-equilibrium transport; channel degradation; sediment sorting; armouring; sediment sampling; reservoir sedimentation.
Prerequisites: None

Course Outline:

1. Sediment properties (1hr)
Physical properties of water and sediment, sediment grade scale, size distribution curve, representative size for graded sediments.

2. Dynamics of sediment movement (3hr)
Analysis of forces acting on a grain, lift and drag coefficients; incipient motion; Shields' diagram and its modifications; effect of sediment non-uniformity on critical shear stress; initiation of motion on steep slopes.

3. Bed forms (3hr)
Bed-forms and their migration; flow regimes and their prediction; flow resistance in mobile-bed channels.

4. Stream power and related theories (2hr)
Concept of stream power; theory of minimum energy dissipation.

5. Bed load transport (4hr)
Analysis and prediction of transport rates; saltation.

6. Suspended sediment transport (5hr)
Suspension criteria; fall velocity; concentration profile; Rouse equation; reference concentration; calculation of transport rates; effect of suspended sediment on velocity distribution; non-equilibrium transport; transport capacity and actual transport rate; convection-diffusion and equation for suspended sediment, its 1-D steady state approximation, depth integration and numerical solution; introduction to 2-D and 3-D models of suspended sediment transport; wash load.

7. Total bed material load (2hr)
Computation of total bed-material load using different methods.

8. Degradation, aggradation, sorting and armouring (1hr)

Computation of depth of degradation and equilibrium bed profile downstream of a dam; sorting and residual transport capacity; active layer and armour coat; stability of sediment mixtures; grain size distribution of armour coat and eroded material; numerical procedure for bed material accounting.

9. Sediment sampling (3hr)

Sampling equipment and methods; laboratory analysis and computation of sediment discharge.

10. Surface erosion and soil loss (2hrs)

Catchment sediment yield estimates; sediment delivery ratio; estimating potential accumulation; flow duration and sediment rating curves.

11. Reservoir sediment deposition (6hrs)

Estimation of reduction in storage capacity; capacity-inflow ratio; trap efficiency and density of deposited sediment; determination of reservoir sediment distribution (revised area, capacity and sediment depths); prediction of reservoir life; reservoir sedimentation studies; bathymetric surveys; sampling from reservoir bottom.

12. Preservation and recovery of reservoir storage capacity (5hrs)

Soil conservation measures to reduce sheet erosion; trapping and retention of sediment by vegetative screens; sedimentation basins; riverbank stabilization; drop inlets and chutes to reduce gully erosion; hydraulic sluicing and other new methods for sediment removal; by-pass channels; reservoir operation rules; flushing; reservoir-emptying; dredging and siphoning.

13. Introduction to fluvial geomorphology (5hrs)

Ordering of stream channels; drainage density; morphological and control variables defining channel geometry; concept of bankfull/dominant discharge; hydraulic geometry relationships, effect of bed and bank material and sediment transport on channel shape; formation of channel features such as bars, riffles and pools, floodplains and river terraces; planform variation; meandering and lateral migration; longitudinal profile and roughness; mechanism of channel slope adjustment; changes and adjustments in equilibrium of river channels; degradation due to change in hydrologic regime.

System Mathematics

4 Credit Hours

Course Outline:

1.	Introduction • History of system analysis and operation research (OR) • Definitions and classification of OR • Models and principles of modeling
2.	Linear programming (LP) and its application • Standard Mathematical /LP Model • Formulation of LP Models • Assumptions of LP Models • Solution Procedure (Graphical solution, Simplex Method, Adapting to other model forms, Other forms of functional function etc.) • Duality Theory • Interpreting the Simplex Tableau, Sensitivity Analysis • LP applications in WR Systems • Examples using GAMS software
3.	Dynamic programming (DP) and its application • Characteristics of DP • Block Diagram, different types of objective functions, curse of dimensionality • Examples of DP for water allocation, reservoir operations • Programming of DP algorithm in Fortran or other programs
4.	Integer programming (IP) and its application • Branch and Bound Algorithm • Examples of IP in water resources systems planning
5.	Non-linear programming and its application • Single variable optimization (local and global optima, sequential seach techniques, convex/concave functions etc) • Steepest hill-climbing Approach – water allocation problem • Multivariate optimization without constraints (local and global maxima, gradient vector and Hessian matrix, Results from calculus, convex/concave functions) • Multivariate optimization with constraints (Standard forms, Lagrange Multipliers, Khun-Tucker conditions) • Applications in Water Resources – River Basin Modeling using GAMS
6.	Network analysis and its application • Network Terminology • Shortest-route Problem • Minimum Spanning Tree Problem • Maximum Flow Problem • CPM/PERT • Water Resources Applications
7.	Emerging tools such as Neural Networks and Fuzzy Optimization and its application in Water Resources

Subject: Hydraulic Structure (Core) 4 Credits

Rationale:

To impart (1) a sound foundation in the planning and hydraulic design of .headworks, dams and appurtenant structures such as spillways and energy dissipators, fish passage facilities, intakes, gates, dam outlet works and valves; (2) insight into physical modeling of these structures; and (3) knowledge of recent developments in subjects.

Catalogue Description:

Headworks; diversion weir; forebay; sediment prevention and bypass; sediment excluder; sediment settling basins; gravity dams; embankment dams; rockfill dams; hydraulic design; spillways; energy dissipators; fish passes; intakes, trashracks; gates; outlet sluices; valves; physical hydraulic models..

Prerequisites: Advanced Hydraulics, Sedimentation Engineering

Course Outline:

1. Headworks for run-of-river projects (10 hrs)

Location and alignment of diversion weir and intake; sediment preventive measures; submerged vanes; sediment bypass using vortex tubes; different types of river and canal intakes; fish screens, louvers and bypass systems; design of sediment excluder, sediment settling basin and flushing conduits.

2. Introduction to dam engineering (4 hrs)

Dam safety and hazard classification; site investigations; diversion during construction; introduction to buttress, prestressed concrete, arch and multiple-arch, cellular or hollow gravity and diaphragm dams.

3. Gravity dams (3 hrs)

Design methods; galleries and openings; construction joints, water stops or seals; foundation treatment; instrumentation.

4. Embankment dams (8 hrs)

Classification; selection criteria; instrumentation; freeboard and top width; safety criteria; seepage through dam section and its control; design of filters and core walls; control of seepage through foundations; upstream impervious blanket; drainage measures; cutoffs; critical slip surface; determination of shear strength and pore pressures; stability analysis methods; introduction to earthquake resistant design; defensive design measures to prevent deformation and cracking; upstream and downstream slope protection; foundation material improvement and densification; foundation preparation and treatment.

5. Rockfill dams (4 hrs)

Requirements of compacted rockfill; shear strength and compressibility; types and cores and facing; bituminous concrete facing; design practices; construction control; placement and compaction.

6. Spillways (6 hrs)

Functions and types; determination of spillway capacity and length; design considerations and examples for free overfall, ogee, chute, siphon, side channel and drop inlet (shaft or morning glory) spillways; emergency spillways.

7. Energy dissipators (4 hrs)

Tailwater considerations for stilling basin; design of hydraulic jump , its types, submerged bucket and impact type stilliing basins.

8. Fish passage facilities (2 hrs)

Different types of fish passes and their features- steep channel (Denil), fish lift; stepped pool and fish lock (Borland) types.

9. Reservoir and dam intakes (4 hrs)

Classification; submergence requirement; velocity requirement and other design considerations; vortices and their prevention; aerations; inlet shapes and transit designs; debris and ice control; floating log booms; stoplogs and bulkhead gates.

10. Trash rack (2 hrs)

Design head, permissible velocity, losses, specifications for spacing and maximum unsupported length of bars; cleaning mechanism; design example.

11. Gates (6 hrs)

Forces acting on gates; classification, components and design considerations for spillway crest gates, sluice gates and intake gates; gate control and operating gear; seals; gate house; illustrative design examples of vertical lift and radial gates.

12 Dam outlets works and valves (5 hrs)

Functions and location of outlet sluices; determination of capacity and profile; intake screen; gate and control gear; aeration and other design considerations; needle valve and disperser; conedispersion valves; hollow-jet valves; butterfly valves.

13. Other hydraulic structures (4 hrs)

Culverts; drops

14. Tunneling in Hydropower (4 hrs)

15. Physical models (4 hrs)

Models of dams, weirs, sluice gates, fish ladders, spillways, intakes.

Subject: River Engineering (Elective) 2 Credits

Rationale:

The aim of this course is to provide a basic understanding of the behaviors of river and riverine systems. The course also provides a broad understanding of functions and uses of river, rivers and their behaviors, bed forms and river dynamics.

Catalogue Description:

Introduction, Functions and Uses of Rivers, Rivers and Their Behaviors, Bed Forms, River Dynamics...

Prerequisites: None

Course Outline:

1. **Introduction** **(2 hrs)**
   Brief historical outline, human interference in river: changes In the riverine environment.

2. **Functions and Uses of Rivers** **(6 hrs)**
   General, natural functions, human use of rivers, hazards due to rivers, effects due to the changes in the catchment area, potential conflicts.

3. **Rivers and Their Behaviors** **(8 hrs)**
   General, types of rivers, upper reaches of rivers, middle reach: rivers in flood plains (Alluvial rivers), Lower reach: Tidal and Delta rivers, other types, river behavior, river plan form, straight river channels, meandering rivers, causes of meander formation, meander characteristics, implications of progressive bank erosion, cyclic movement of meanders, meander relationships, braided rivers, causes of braiding, characteristics of a braided pattern.

4. **Bed Forms** **(6 hrs)**
   Formation of Bed Forms, Types of bed forms, field data of bed forms, implication of bed forms, prediction of shape and dimensions of bed forms.

5. **River Dynamics** **(12 hrs)**
   General, Fluvial processes, Morphological Prediction, Improved Lane's Balance

Subject: Time Series Analysis (Elective) 2 Credits

Rationale:

To enhance the students understanding and the possibilities and limitation of different types of time series models through lectures and practical model application..

Catalogue Description:

Introduction, Characteristics of hydrologic series, Statistical principles and techniques for time series modeling, Stochastic Processes, Time Series Modeling, Generation of random variates..

Prerequisites: None

Course Outline:

1. Introduction (2 hrs)

Stochastic processes and time series, Time series modeling, Physical basis of time series modeling in hydrology, Applicability.

2. Characteristics of hydrologic series (2 hrs)

Type of hydrologic series, General properties of hydrologic time series.

3. Statistical principles and techniques for time series modeling (8 hrs)

Probability function and distribution function, Derived distributions, Chebyshev's Inequality, moment generating function, normal distribution, Central limit theorem, Estimation of the parameters of the distribution; Methods of moments, Method of maximum likelihood, selection of distribution.

4. Time Series Modeling (25 hrs)

Classification of time series, Components of time series, Method of investigation, estimation of the auto-correlation coefficient, Correlogram of an independent process, Moving average process, Auto regressive process, Goodness of fit for annual AR models; Test on the assumptions of the model, Comparison of the historical and model correlograms, Test of Parsimony of parameters, Generation and forecasting using annual AR models; Auto regressive moving average process, application in flood forecasting system, Autoregressive integrated moving average process, Univariate seasonal models; Thomas-fiering model, Daily flow model, Introduction to multivariate model; spectral analysis; introduction, Line spectrum.

5. Generation of random variates (5 hrs)

Uniformly distributed random numbers; Mid square technique, Mid-product technique, Mixed congruential method, testing the random numbers sequence, generation of normal random numbers; The inverse transformation method, the central limit theorem method, Box-muller method.

Subject: GIS and Remote Sensing (Elective) 4 Credits

Rationale:

This course introduces principles, concepts and application of Geographic Information System (GIS); a decision support tool for planners and managers of spatial information. Database development, manipulation and spatial analysis techniques for information generation will be taught. Students will have the scope of using GIS for applications in their related fields such as natural resource management, environment, civil engineering, agriculture, information system, etc will be discussed through miniproject and laboratory exercises.

Catalogue Description:

Mapping Concept, Data Structure, Data Management Techniques, Data Acquisition, Global Positioning System Interface, Data Manipulation and Analysis, Map Output Generation.

Prerequisites: None

Course Outline:

1. **Introduction and Overview of GIS and Arcview** **(3 hrs)**
   Definition of a GIS features and functions; why GIS is important; how GIS is applied; GIS as an Information System; GIS and cartography; contributing and allied disciplines; GIS data feeds; historical development of GIS.

2. **GIS and Maps** **(3 hrs)**
   Map Projections and Coordinate Systems; Maps and their characteristics (selection, abstraction, scale etc); automated cartography versus GIS; map projections; coordinate systems; precision and error.

3. **Spatial Data Models** (**3 hrs)**
   Concept of data model; raster data model; compression; indexing and hierarchical data structures; vector data model; topology; TIN data model.

4. **Data Sources** **(3 hrs)**
   Data input and Data Quality; Major data feeds to GIS and their characteristics; maps, GPS, images, databases; commercial data; location and evaluating data; data formats; data quality; metadata.

5. **Database Concepts** **(3 hrs)**
   Database concepts and components; flat files; relational database systems; data modeling; views of the database; normalization; databases and GIS.

6. **Vector Analysis** **(5 hrs)**
   Data management functions; Data Analysis functions.

7. Spatial Analysis (5 hrs)

Spatial interpolation methods; raster analysis including topological overlay; Map calculations; statistics; integrated spatial analysis.

8. Surface Model (3 hrs)

DEM; slope; aspect; other raster functions.

9. River network generation (3 hrs)

Flow direction; flow accumulation; river network; and watershed boundary delineation.

10. GPS (3 hrs)

Basic concept of GPS; How GPS works; DGPS; Errors in GPS; application.

11. Introduction of Remote Sensing (3 hrs)

Concept of Remote Sensing; Electro Magnetic Spectrum and windows; Spectral signature of different landuse; Introduction to different satellites; Resolutions in RS; Application of Remote Sensing.

12. Making Maps (2 hrs)

Map functions in GIS; map design; map elements; choosing a map type; Exporting map in different format, printing a map.

13. Project Work (6 hrs)

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Water Resources Planning and Management

4 Credit Hours

Pre-requisite: System Mathematics

Course Outline:

1.	Systems Concepts of Water Resources/Hydropower Systems and Modeling, IWRM and Adaptive Management principles and concepts, River Basin Concept, National Water Resources Strategy, National Water Plan, Hydropower Policy
2.	Engineering economics, CBA, Project Appraisal, Economic and Financial Analysis, Examples
3.	Water Resources Systems Modeling
3.1	Water resources/hydropower investment problem: Sequencing and scheduling with LP and DP, Introduction to WASP (Power System Planning Tool)
3.2	Simulation Modeling: reservoir simulation, deterministic and stochastic simulation, Stochastic hydrology- Thomas Fiering Method, Matalas Method, Standard Operating Rules, Hedging Rule
3.3	Reservoir Operations- Mass Curve (Ripple Method), Sequent Peak Method,
3.4	Chance constrained models : Linear decision rules, deterministic and stochastic reservoir operation
3.5	Dynamic programming (DP): deterministic DP (DDP), stochastic DP (SDP) for reservoir operation , Markov chains, Applications
3.6	Modern techniques: Artificial Neural Networks and Fuzzy Optimization Applications
3.7	River Basin Planning Models and Case Studies: HEC3, HEC5, WEAP, MIKE BASIN etc
4.	Water Resources Assessment Techniques
4.1	General: Performance Assessment, Risk Analysis, Reliability, Resiliency, Vulnerability
4.2	Social Assessment Criteria
4.3	Environmental Assessment Criteria
4.4	Multiple criteria decision making (MCDM) Techniques • Compromise Programming • Analytical Hierarchical Process (AHP) • Electre I/ II • Goal Programming
5.	Legal Issues in Water Resources Management- National Laws, International Law and Conventions, Regional Cooperation prospects • National Water Resources Policy • Water resources law • International Cooperation and issues of downstream benefits • Hydropower Policy of Nepal • Electricity Act of Nepal
6.	Institutional Issues • Water Administration in Nepal • Institutional cooperation for the development of boundary and transboundary rivers

Subject: Group Project (Core) **4 Credits**

Subject: Irrigation and Drainage Engineering (Elective) 4 Credits

Rationale:

To develop know how in planning, design, development, operation, maintenance and management of irrigation and drainage projects.

Catalogue Description:

Planning of irrigation and drainage projects; irrigation water requirement and assessment of water availability; layout and design irrigation headworks; design of surface; sprinkler and trickle systems; command area development; drainage of irrigated lands; operation, maintenance and management of irrigation systems..

Prerequisites: None

Course Outline:

1. **Planning of irrigation and drainage projects** **(3 hrs)**
   Farming systems; Irrigation related policy, strategy, plan and legal provisions; Participatory approach in irrigation development; Irrigation planning; Drainage in irrigated agriculture.

2. **Head works design** **(6 hrs)**
   Selection and layout of head works; Channel stabilization; Design of weirs and barrages.

3. **Irrigation water requirement and assessment of water availability** **(6 hrs)**
   Consumptive use of water; Factors affecting consumptive use of water; cropping pattern and crop coefficients; Irrigation water requirements; Irrigation efficiencies; Irrigation scheduling; Irrigation water quality; Assessment of water availability.

4. **Surface system design** **(4 hrs)**
   Furrow system design; level basin systems; Graded border system designs.

5. **Sprinkler system design** **(4 hrs)**
   Uniformity and adequacy of application; Evaporation and wind drift; Components of system design; Distributed system design and layout; Center and pivot and linear move systems; Big gun and boom sprinkler systems.

6. **Trickle system design** **(3 hrs)**
   Emitters or drippers; Lateral hydraulics; Filtration and water treatment systems; Fertilizer injection systems.

7. **Command area development** **(6 hrs)**
   Layout of irrigation units and field channels; Outlets and their suitability; Adjustable proportional modules; Simple pipe outlets and orifices; Network design under tertiary; Conjunctive use of surface water and ground water.

8. Drainage of irrigated lands (5 hrs)

Need of drainage; Sources and control of excess water; lowering of water table; Design of open drains; Design of tile drains; Maintenance of drains; Pumping of drainage water; Re-use of drainage water.

9. Operation, maintenance and management of irrigations systems (3 hrs)

Organization and management: organization involved in irrigated agriculture; Water Users' Association; On-farm water management; Management of operation and maintenance; O and M costs and cost recovery; Issues of irrigation service fees; Legal and institutional aspects; Operation of irrigation systems; Reasons and consequences of poor operation; Irrigation deliveries; Water distribution methods and procedures; Specific operation procedures; Staff requirements and duties; Maintenance of irrigation systems; Requirements and categories of maintenance; Specific maintenance activities; Maintenance procedures and implementation; Staff requirements and duties; Maintenance plants and equipments.

Subject: Hydropower Engineering (Elective) (4 Credits)

Rationale:

To impart(1) essential knowledge in the planning of hydropower scheme(2) insight into the principles of hydraulic design of conveyance systems, and planning and design of power house structures;(3) Knowledge of recent developments in the subject..

Catalogue Description:

Planning of hydropower schemes;turbines and generators; transmission of power and transformers;Power canal;forebay;headrace and tailrace tunnels; penstocks; pressure conduits;shafts;surge tanks;draft tubes;power house design and dimensioning;underground power stations.

Prerequisites: None

Course Outline:

1. **Planning and investigations** **(6 hrs)**
   Preliminary studies; site selections; suitability; of different structures (dams, spillways, intakes, tunnels, powerhouse channels etc):civil engineering investigations for engineering feasibility; planning considerations for changes in head; considerations for construction power and camps etc; turbine selections; determination of number of units and plant operation strategy; overall layout.

2. **Turbines** **(3 hrs)**
   Determinations of runner discharge diameter, setting of turbine with respect to head and tail water levels; speed regulations through governors.

3. **Electrical aspects** (**3 hrs)**
   Design(cross-section and slope) of power canals; economic considerations in design; canal alignment; cut and fill; canal lining; general layout, intake and bypass arrangements for the forebay.

4. **Power canal and forebay** **(3 hrs)**
   Design (cross-section and slope)of power canals; economic considerations in design; canal alignment; cut and fill; canal lining; general layout, intake and bypass arrangements for the forebay.

5. **Tunnels** **(5 hrs)**
   Headrace and tailrace tunnels; free flow and pressure tunnels; friction losses; geometric and hydraulic design of tunnel cross sections and transitions; economic diameter; limiting unregulated length; limiting profile; design of lining (concrete ,steel, prestressed concrete)and supports. shortcrete; design of drainage and auxiliary tunnels; portals and plugs grouting; intstrumentation.

6. Penstocks, pressure conduits and shafts (6hrs)

Design stresses; friction loss and head loss in bends; types of penstocks; economic diameter of penstock; penstock shell thickness; number of penstocks and equivalent diameter; penstock joints and stiffeners; anchors and supports (saddies); bends; bifurcations; manholes; butterfly control valves; air valves; design of reinforced concrete around a pressure conduit; design of steel liner and stiffener rings for a conduit.

7. Draft tubes (3hrs)

Tailrace and other conditions governing design; exit velocity and losses; hydraulic design and dimensioning; relief valves, screens and gates; physical models.

8. Powerhouse arrangements (3hrs)

Classification and typical general arrangements; vertical sub-division; considerations in dimensioning; longitudinal and transverse joints; requirement for control room, administration, fire fighting, water supply, ventilation and other accommodation requirements.

9. Power house design preliminaries (6hrs)

-Determination of weight of turbine, diameter of turbine shaft, dimensions of the spiral casing and draft tube, weight and dimension of the generator.

-Determination of sizes, weights, positions, and erection and support requirements of the generator control equipment, turbine control equipments, supervisory and telecom equipment, and auxiliary equipments such as governors, servomotors, air compressors, pumps, transformers, switchgear, cable passages and ducts.

-Determination of crane loads and clearance; determination of foundation characteristics.

10. Power house substructure (4hrs)

Form and size determination of the substructure based on the types of turbine, generator and associated equipments; constructional requirements of turbines; horizontal and vertical shaft arrangement; design loads on draft tube, scroll case and generators-supporting structures.

11. Powerhouse superstructure (4hrs)

Preliminary dimensioning of machine (unit) bay- unit spacing, width of bay, height of crane from generator floor; location and dimensioning of erection (loading) bay and control room; design stresses and moments.

12. Underground power houses (4hrs)

Principal types and hydrodynamic problems associated with each type; number and sizes of cavities, their location and alignment; arrangements of various components and equipment; supporting arrangements and design loads; some typical general arrangements.

13. Costing, scheduling and contracting (5hrs)

Preliminary cost estimation for equipment, civil works and transmission lines; construction scheduling; permit applications; types of contracts; bidding and contract documents; evaluation of bids; contract administration.