TRIBHUVAN UNIVERSITY

INSTITUTE OF SCIENCE AND TECHNOLOGY

KIRTIPUR, KATHMANDU, NEPAL

M.SC. SYLLABUS

FOR

MASTER OF SCIENCE IN HYDROLOGY AND METEOROLOGY

PREPARED BY

HYDROLOGY AND METEOROLOGY SUBJECT COMMITTEE

January 2024

Introduction

The imperceptible influence of weather extends its impact on our world, shaping everything from the crops we cultivate to the flights we embark upon. Meteorology, the study of the atmosphere, and its companion discipline, hydrology, which focuses on the study of water resources, function as the unseen architects of our daily existence. Envision a farmer observing the sky, meticulously deciphering cloud formations to anticipate the timing of the next irrigation. Alternatively, envision a hydrologist equipped with advanced models, predicting river flow and safeguarding communities from potential floods. These glimpses offer a peek into the dynamic realm of hydrology and meteorology, a domain replete with challenges and opportunities.

Hydro-meteorology, the fusion of meteorology and hydrology, assumes a central role in comprehending this dynamic interplay. It explores the hydrologic cycle, the life force of the Earth, forecasting rainfall patterns, managing water resources, and mitigating potential disasters. Imagine the ability to forecast impending heavy rain and snowstorms, along with flash floods, ensuring optimal irrigation for thriving crops.

For Nepal, nestled amidst the majestic Himalayas, meteorological and hydrological studies are not just a choice, but a necessity. Snow and glaciers are the headwaters feeding life-giving rivers, and monsoon precipitation dance with glacial rhythms, carving unique landscapes and fostering diverse ecosystems. Yet, this beauty comes with challenges. Understanding weather and climate patterns becomes critical for flood forecasting, glacier monitoring, and ensuring water security for a nation heavily reliant on the agriculture and tourism.

This Master's program in Hydrology and Meteorology equips students to understand and address Nepal's complex water challenges. Students will master advanced forecasting techniques to predict glacial lake outbursts, optimize crop yields amidst unpredictable weather patterns, and ensure sustainable water resource management.

Tribhuvan University’s long-standing commitment to meteorology and hydrology is evident in its establishment of the Bachelor of Sciences program in 1973 at Tri-Chandra College and the Masters of Sciences program in 1988 by the Central Department of Hydrology and Meteorology (CDHM) in Kirtipur under the Institute of Science and Technology (IOST). The primary objective of these courses is to produce skilled professionals and conduct scientific research in hydrology, meteorology, glaciology, and climate change. The secondary objective is to provide students with comprehensive knowledge aligned with the latest trends and development in the field globally.

Eligibility and Admission Criteria:

To be eligible for admission to the M.Sc. in Hydrology and Meteorology program, applicants must hold a 4-year Bachelor's Degree (B.Sc.) or equivalent in one of the following:

- Hydrology and Meteorology: preferred stream.
- Physical Sciences: open to students with strong backgrounds in Physics, Mathematics, Statistics, Engineering, Forestry or Agriculture: open to students with at least a second division or equivalent degrees recognized by Tribhuvan University.

Entrance Examination:

All applicants must appear and pass an entrance examination conducted by the Institute of Science and Technology. Admission is strictly based on merit.

Program Details:

- Medium of Instruction: English
- Duration: Four semesters (two academic years).
- Total Credits: 64
- Total Full Marks: 1600
- Teaching Hours:1650

Theory:

- One credit equals 15 lecture hours and 25 marks.
- One theory paper of one credit has one hour of lecture per week.

Practical:

- One credit equals 45 laboratory hours or research work and 25 marks.
- One practical paper of one credit has three hours of practical work per week.

Evaluation:

- Passing marks are required in all theory and practical subjects separately for graduation.
- Internal examinations (40% of total marks) are mandatory for appearing in final examinations.
- The pass marks of all theory, practical, research work and seminar are 50%.
- The IOST-TU conducts final examinations, while CDHM conducts internal examinations.

- Examination duration is one hour for one credit of theory and three hours for one credit of practical/research activities.

Courses Distribution: First Semester

SN	Course Code	Course Name	Credits	Marks
1	Hymet.501	Atmospheric Thermodynamics and Cloud Physics	3	75
2	Hymet.502	Paleoclimatology	3	75
3	Hymet.503	Groundwater Hydrology	3	75
4	Hymet.504	Dynamic Meteorology	3	75
5	Hymet.505	Environmental Hydro-meteorology	3	75
6	Hymet.506	Meteorology Practical	2	50
7	Hymet.507	Instrumentation and Hydrology Practical	2	50
8	Hymet.508	Fieldwork /Report	1	25
		Total	**20**	**500**

Courses Distribution: Second Semester

SN	Course Code	Course Name	Credits	Marks
1	Hymet.551	Synoptic and Tropical Meteorology	3	75
2	Hymet.552	Cryosphere	3	75
3	Hymet.553	Water Resources Planning and Management	3	75
4	Hymet.554	Radar and Satellite Meteorology	3	75
5	Hymet.555	Aviation Meteorology	2	50
6	Hymet.556	Micrometeorology	2	50
7	Hymet.557	Weather Analysis and Forecasting Practical	2	50
8	Hymet.558	Water Resources and Cryosphere Practical	2	50
		Total	**20**	**500**

Courses Distribution: Third Semester (Compulsory)

SN	Course Code	Course Name	Credits	Marks
1	Hymet.601	Climate Change and Natural Disasters	2	50
2	Hymet.602	Seminar	1	25
3	Hymet.603	Internship	1	25
4	Hymet.604	Project/Community Works, Fieldwork	2	50
5		Elective I	2	50
6		Elective II	2	50
7		Elective III	2	50
8		Elective Practical	2	50
		Total	**14**	**350**

Courses Distribution: Third Semester (Elective- Climate Science Stream)

SN	Course Code	Course Name	Credits	Marks
1	Hymet.611	Climate Modeling	2	50
2	Hymet.612	Applied Climate Science	2	50
3	Hymet.613	Climate Change Mitigation, Adaptation, and Resilience	2	50
4	Hymet.614	Applied Climatology and Climate Modeling Practical	2	50
		Total	**8**	**200**

Courses Distribution: Third Semester (Elective- Water Resources Stream)

SN	Course Code	Course Name	Credits	Marks
1	Hymet.621	Hydrological Analysis	2	50
2	Hymet.622	River Hydrology	2	50
3	Hymet.623	Sedimentology	2	50
4	Hymet.624	Hydrological and Sediment Modeling Practical	2	50
		Total	**8**	**200**

Courses Distribution: Third Semester (Elective- Cryosphere Stream)

SN	Course Code	Course Name	Credits	Marks
1	Hymet.631	Remote Sensing and Cryosphere Modeling	2	50
2	Hymet.632	Advance Glaciology	2	50
3	Hymet.633	Snow and Permafrost	2	50
4	Hymet.634	Snow Modeling and Cryosphere Practical	2	50
		Total	**8**	**200**

Courses Distribution: Fourth Semester

SN	Course Code	Course Name	Credits	Marks
1	Hymet 651	Project Management	2	50
2	Hymet 652	Thesis	8	200
		Total	**10**	**250**

Courses Distribution: Non-credit Course

SN	Course Code	Course Name	Credits	Marks
1	Hymet.661	Statistical Application for Hydro-meteorological Data Analysis		
2	Hymet. 662	GIS and Remote Sensing Applications on Hydro-meteorology		
3	Hymet. 663	Natural Resources Management		
4	Hymet. 664	Socio-economic Aspect of Climate and Water Resources		
5	Hymet. 665	Springshed Management		
6	Hymet. 666	Application of Field and Remote Sensing Technique for Snow and Glacier Study		
7	Hymet. 667	Monsoon Meteorology		
8	Hymet. 668	Environmental Impact Assessment (EIA)		
9	Hymet. 669	Programming in Hydro-meteorology		
10	Hymet. 670	Conflicts in Water Resources		
11	Hymet. 671	Economics, Legal and Policy Dimensions of Climate Change		
12	Hymet. 672	Renewable Energy Resources		

Courses Distribution: Bridge Course for Non-Meteorology Students

SN	Course Code	Course Name	Credits	Marks
1	Hymet. 511	Applied Meteorology	4	
2	Hymet. 512	Applied Hydrology	2	

Course Title: Atmospheric Thermodynamics and Cloud Physics **Credit Hrs: 3**

Course No: Hymet 501 **Lecture Hrs: 45**

Nature of the Course: Theory (Compulsory) **Full Marks: 75**

Semester: I **Pass Marks: 37.5**

Course Contents:

Review and Basic Concepts: System, state, equilibrium, temperature; energy, work; reversibility. (2 hrs.)

Gas Laws and Atmospheric Properties: Boyle's law, Charles's law, and the ideal gas law, equation of state for dry air and water vapor, virtual temperature and its application, moisture parameters: mixing ratio, specific humidity, and saturation vapor pressure, relative humidity and its variations (dew point, frost point). (5 hrs.)

First Law of Thermodynamics: Reversible and irreversible work, Joule's Law and specific heats, enthalpy and its applications, adiabatic processes and concepts of air parcels, dry adiabatic lapse rate and its derivation, heat capacity and potential temperature, thermodynamic diagrams (e.g., skew-T log-P diagram). (5 hrs.)

Water Vapor in the Atmosphere: Latent heat and phase changes, saturation, saturation mixing ratio, and the Clausius-Clapeyron equation, lifting condensation level and its determination, wet-bulb temperature and its applications, saturated adiabatic lapse rate and its derivation, stability and instability in the atmosphere, carnot cycle and its efficiency, entropy and its significance, Clausius-Clapeyron equation and its applications, generalized statement of the second law, thermodynamic potentials: Helmholtz and Gibbs functions, stable and unstable equilibrium and state transitions, enthalpy and its role in thermodynamics. (10 hrs.)

Atmospheric Aerosols: Aerosol sources over land and ocean surfaces, natural and anthropogenic sources of aerosol particles, aerosol size distribution and different modes (Nucleation mode, Aiken/Nuclei mode, Accumulation mode, and Coarse mode particles), instrumentation for aerosol measurements: techniques and instruments used to measure aerosol properties, removal processes of Aerosol. (3 hrs.)

Cloud Condensation Nuclei (CCN) and Ice Nuclei (IN): Measurement techniques: Methods used to measure the concentration and size of CCN/IN, concentrations over land and ocean surfaces, distribution and variations in CCN/IN concentrations, supersaturation dependence:

Relationship between CCN activation and the level of supersaturation in the atmosphere, properties of CCN, physical and chemical properties of aerosol particles that act as CCN. (5 hrs.)

Nucleation of Droplets and Ice: Homogeneous nucleation of droplets, Kohler Theory of nucleation of water vapor condensation (Derivation, theory and application of Kohler equation that includes Kelvin Equation and Raoult's Law), hygroscopic growth, Kelvin equation, Raoult's law, structure of ice, homogeneous nucleation of ice, heterogeneous nucleation of ice. (5 hrs.)

Droplet Growth Theory: Diffusional growth: Growth of cloud droplets through diffusion of water vapor, collision-coalescence growth, growth of cloud droplets through collision and merging with other droplets, evaporation of large drops accounting for ventilation, loss of water from larger droplets due to air motions and ventilation effects, stochastic processes: Random processes influencing droplet growth and collisions, fall mode of large drops: droplet behavior during fall and precipitation formation, broadening of cloud droplet spectra: Theories explaining the broadening of droplet size distributions in clouds. (5 hrs.)

Ice Crystal Growth Mechanisms: Growth from the vapor phase; Habit theory: theoretical framework describing the characteristic shapes and structures of ice crystals, depositional growth rates and effects of ventilation, growth by aggregation, growth by riming, formation of hail and growth rate of hailstones, melting of ice particles, ice particle multiplication mechanisms. (5 hrs.)

Text Book

Pruppacher, H.R. and Klett, J.D. (2010), Microphysics of Clouds and Precipitation.

Reference

Khvorostyanov, V.I, Curry. JA. (2014), Thermodynamics, Kinetics, and Microphysics of Clouds. Cambridge: Cambridge University Press.

Pandharinath, N. (2007), The Science of Weather and Environment, B S Publications, Hyderabad.

Course Title: Paleoclimatology **Credit Hrs: 3**

Course No: Hymet 502 **Lecture Hrs: 45**

Nature of the Course: Theory (Compulsory) **Full Marks: 75**

Semester: I **Pass Marks: 37.5**

Course Contents:

Introduction of Paleoclimatology: Paleoclimatology, the development of the Earth's climate system on geological timescales, Proxy tools for paleoclimate, importance of paleoclimate in Nepalese context, the evaluation and interpretation of paleoclimatic proxy data. (3 hrs.)

Introduction of Dendrochronology: Introduction of dendrochronology, History of dendrochronology, Basic principle of dendrochronology, various tree rings and correlation with temperature and precipitation, subfield of dendrochronology. (5 hrs.)

Dendroclimatology: Factors affecting tree growth, Methods of dendroclimatology, application of dendroclimatology, climate indices, dendrohydrology, archeological use of climate reconstruction, use of climate reconstruction for future prediction. (5 hrs.)

Field and Laboratory Methods: Filed gears, Site selection and description, Various methods of tree ring sampling, Description of tree ring instrument, Types of borers/tree corer, cleaning/sharpening of incremental Borer, storing of samples, sample preparation, Analysis of cores and cross sections, measuring of samples and cross dating and standardization. (5 hrs.)

Computer Programs and Statistical Methods: Statistics in dendrochronology, express population signal, measuring program, dendrochronology program library, FMT, COFECHA, EDRM, ARSTAN, PRECON, DENDROCLIM, Spectral Analysis. (5hrs.)

Fundamentals of Stable Isotopes: Introduction of stable isotopes, relative abundances of hydrogen and oxygen isotopes, isotopic compositions of molecular water, understanding delta (d) notation, standard water (VSMOW, SLAP), internal laboratory standards (ILS), stable water isotopes measurement network (GNIP, TNIP). (3 hrs.)

Isotopic Fractionation: Evaporation and condensation, vapour pressure, basic concept of isotopic fractionation, equilibrium/kinetic fractionation, condition of isotopic equilibrium, factors affecting kinetic effects, fractionation coefficient, enrichment factor, Rayleigh fractionation model. (5 hrs.)

Isotopic Evolution: Isotopic evolution in the hydrological processes, climatic controls on isotopes in precipitation (altitude effect, amount effect, temperature effect). (5 hrs.)

Isotopic Variations in the Hydrological Cycle: Meteoric water line (MWL), Global Meteoric Water Line (GMWL), deuterium excess (d-excess), factors affecting d-excess. (5 hrs.)

Water Sampling: Various methods of water sampling, precipitation sampling procedures, river water sampling procedures. (1 hr.)

Importance of Stable Isotope Studies: Influence of westerlies and monsoon, precipitation isotope studies in the Himalayan region, monsoon onset criteria using stable isotope in precipitation, water isotopes as a climate proxy (reconstruction of paleo-climate, estimation of past temperature variation). (5 hrs.)

Text Books

Clark, I., Fritz, P. (1997). Environmental isotopes in hydrology. Lewis Publisher, Boca Raton, Fla**.**

Environmental isotopes in the hydrological cycle; Principles and Applications: International Atomic Energy Agency (IAEA) and United Nations Educational, Scientific and Cultural Organization (UNESCO).

Speer, J. 2010. Fundamentals of Tree-Ring Research. University of Arizona Press.

References

Cook E.R. & Kairiukstis L.A. (Editors) 1990, Methods of Dendrochronology. Kluwer Academic Publishers.

Fritts H.C. (1976), Tree Rings and Climate. Academic Press.

Hughes M.K., Kelly P.M., Pilcher J.R., Lamarche V.C., Jr. (Editors) 1982, Climate from tree rings. Cambridge University.

Course Title: Groundwater Hydrology **Credit Hrs: 3**

Course No: Hymet 503 **Lecture Hrs: 45**

Nature of the Course: Theory (Compulsory) **Full Marks: 75**

Semester: I **Pass Marks: 37.5**

Course Contents:

Introduction: Definition, scope of groundwater hydrology, availability of groundwater on Earth and in Nepal, history, importance, and application of groundwater hydrology. (1 hr.)

General Geology: Origin, age, and the structure of earth, plate tectonics, concept of Gondwana land, continental drift theory, faulting, folding, and structure in rocks, relationship between geologic structures and earth materials, significance of geological structures, rock cycle, composition, occurrence, and formation of igneous, sedimentary, and metamorphic rocks, identification of igneous, sedimentary, and metamorphic rocks, units, sampling, diagnostic features, making rock description, regional geology of Nepal. (4 hrs.)

Soil Science and Groundwater: Soil, classification of soil, soil gradation, soil profile, seepage and soil-water interaction, rocks and mineral, weather and soil formation, soil forming factors and process, soil texture, structure and consistency, porosity and earth materials, forces acting in groundwater flow, water table, soil moisture, vertical distribution of groundwater, zone of aeration, zone of saturation, types of aquifers and its characteristics**.** (4 hrs.)

Groundwater Movement: Groundwater basin, Darcy's law, experimental verification, validity of Darcy's law, permeability, hydraulic conductivity, determination of hydraulic conductivity, groundwater flow rates, groundwater flow direction, dispersion, groundwater tracers, general flow equations, unsaturated flow. (5 hrs.)

Well Hydraulics: Mechanical energy, hydraulic head, flow nets, steady unidirectional flow, steady radial flow to well, well in uniform flow, unsteady radial flow to confined, unconfined and leaky aquifer, well flow near aquifer boundary, multiple well system, partially penetrating well, well flow for special condition, horizontal well, well loss, specific capacity and well efficiency. (5 hrs.)

Well Development, Groundwater Levels and Environmental Influences: Test well and well logs, method of constructing shallow and deep wells, well development, testing yield of the well, pumping equipment, protection of the well, well rehabilitation, and slug test, Time variations of

level, stream flow and groundwater level fluctional due to meteorological factors, urbanization, earthquakes, external loads, land subsidence. (3 hrs.)

Spring Water Assessment and Management: Spring source and rural livelihood, Spring source Identification, concept of springshed, spring type identification, Classification of spring, Spring yield measurement, small stream measurement, Spring yield monitoring, Rapid environmental assessment, Spring water quality assurance, Spring water quality sampling, hot water springs, Protection of spring, groundwater and hydrological cycle, hillslope hydrology and stream flow generation, baseflow recession and bank storage, groundwater lake interaction. (4 hrs.)

Hydro-geochemistry: Properties of water, inorganic and organic solutes, solute concentration, chemical reactions, activity, and effective concentration, reaction rates and equilibrium, mineral dissolution and precipitation, aqueous phase reactions, metal complexes, oxidation and reduction, biochemical redox reactions, non-polar organic compounds, stable isotopes and the origin of water, and radioisotopes. (4 hrs.)

Water Quality and Groundwater Pollution: Measurement and analysis of water quality, chemical, physical, and biological methods, water quality criteria, groundwater quality monitoring, sources of pollution, point and non-point sources, distribution of contaminants in the subsurface, pollution attenuation, mass transport of pollutants, pollution from landfills, agriculture, and industry, physico-chemical properties of organic compounds; and sorption and partitioning of organic contaminants in soils and sediments. (4 hrs.)

Investigation of Groundwater and Artificial Groundwater Recharge: Surface investigation, (geological methods, remote sensing, geological exploration method, seismic refraction method, gravity and magnetic method), subsurface investigation (test drilling, water level measurement, different logging method), concept of artificial recharge, recharge methods, wastewater for reuse, soil aquifer treatment system, recharge mounds, stormwater infiltration basin mound, induce recharge, innovative approach. (4 hrs.)

Ground Water Models: Introduction of models used in groundwater, modeling groundwater movement, water contamination, saltwater intrusion, Ghyben- Herzberg relation between fresh and groundwater, estimation of groundwater minerals. (4 hrs.)

Groundwater Development and Management: Groundwater basin management, groundwater basin investigation, data collection and field work, dynamic equilibrium in natural aquifers, groundwater budget, management potential of aquifer, groundwater management model,

protection of water quality in aquifers, yield of groundwater; alternate basin yield, evaluation of perennial yield, groundwater mining, and cyclic storage, conjunctive use of ground and surface water, status and potential of groundwater development and utilization in Nepal, policies and groundwater laws, traditional knowledge of groundwater management in Nepal. (3 hrs.)

Text Books

Raghunath, H. M. (1987), Groundwater, 2nd edition, New Age International (P) Limited, Publishers, New Delhi.

Todd, K. D. (1980), Groundwater Hydrology 2nd edition, John Wiley & Sons Inc., New York.

References

Chow, V.T. Maidment, D.R. and Mays, L.W. (1988), Applied Hydrology. McGraw-Hill Education, International Edition, Civil Engineering Series, New York.

Fetter, C.W. (1990), Applied Hydrogeology, 2nd edition, CBS Publishers and Distributors, New Delhi.

Raghunath, H. M. (2006), Hydrology Principles, Analysis, Design, 2nd edition, New Age International (P) Limited, Publishers, New Delhi.

Reddy, P. J. (2011), A Text Book of Hydrology, 3rd edition, Laxmi Publications P. Ltd., New Delhi, India.

Subramanayam, K. (2008), Engineering Hydrology, 3rd edition, TATA McGraw Hills Publications Ltd., New Delhi.

Course Title: Dynamic Meteorology **Credit Hrs: 3**

Course No: Hymet 504 **Lecture Hrs: 45**

Nature of the Course: Theory (Compulsory) **Full Marks: 75**

Semester: I **Pass Marks: 37.5**

Course Contents:

Introduction: Different coordinate systems, vector notations, differential and integral calculus, fundamental equations in height and pressure coordinates, Scale analysis, force balanced in the atmosphere and basic conservation principles. (5 hrs.)

Circulation and vorticity: The circulation theorem, vorticity in cartesian and natural coordinate, potential vorticity, cartesian coordinates form of vorticity equation, vorticity equation in isobaric coordinate, scale analysis of vorticity equation, barotropic (Rossby) potential vorticity equation, baroclinic (Ertel) potential vorticity equation. (5 hrs.)

Quasi-geostrophic analysis: The observed structure of extratropical circulations, the quasi-geostrophic approximation and scale analysis, beta-plane approximation, the quasi-geostrophic vorticity equation, quasi-geostrophic prediction of geopotential tendency, the quasi-geostrophic potential vorticity equation, diagnosis of vertical motion, the omega equation, the ageostrophic circulations, idealized model of a baroclinic disturbances. (8 hrs.)

The Planetary Boundary Layer: Atmospheric turbulence, Bossineq approximation and Reynolds averaging, planetary boundary layer momentum equation, well mixed boundary layer, flux gradient theory, the mixing length hypothesis, the Ekman layer, the surface layer, the secondary circulation, and spin down. (5 hrs.)

General circulation: Nature of the problem, zonally averaged circulation, angular momentum budget, Lorenz energy cycle, longitudinally dependent time-averaged flow, low-frequency variability, laboratory simulation of the general circulation, numerical simulation of the general circulation. (5 hrs.)

Atmospheric Oscillations and Atmospheric Waves: The perturbation method, properties of waves, simple wave types, internal gravity (Buoyancy) waves, gravity waves modified by rotation, adjustment to geostrophic balance, Rossby waves. (5 hrs.)

Tropical Dynamics: Observed structure of large-scale tropical circulations, condensation heating, equatorial wave theory, steady forced equatorial motions, monsoon dynamics: basics. (5 hrs.)

Numerical Modeling and Prediction: Historical background, filtering meteorological noise, numerical approximation of the equations of motion. Primitive Equation Models: Parameterization, Data Assimilation, Predictability and Ensemble Prediction Systems, Various types of NWP Models, Applications of NWP Models. (7 hrs.)

Textbook:

Holton J. R., An introduction to dynamic meteorology, Academic Press Inc., New York.

Martin, J. E., Mid-Latitude Atmospheric Dynamics: A First Course, Willey and Sons Ltd, England.

References:

Marshal, J and Plumb, A.R. Atmosphere (2007), Ocean and Climate Dynamics: An Introductory Text. *Elsevier: International Geophysics Series*.

Haltiner G. J., and Martin F., Dynamical and physical meteorology, McGraw, Hill Book Co, New York

Hess S.L., Introduction to theoretical meteorology, Holt Rinehart and Winston, New York, 1959

Albright John G., Physical Meteorology, Prentice Hall Inc., New York.

Course Title: Environmental Hydro-meteorology **Credit Hrs: 3**

Course No: Hymet 505 **Lecture Hrs: 45**

Nature of the Course: Theory (Compulsory) **Full Marks: 75**

Semester: I **Pass Marks: 37.5**

Course Contents:

Air Pollution: Introduction of air pollution and criterion pollutants, indoor air pollution; classification of air pollutants, particulate matter (PM_{10}, $PM_{2.5}$, Atmospheric Aerosols), Gases (Carbon monoxide, Carbon dioxide, Sulphur dioxide, Oxides of Nitrogen, Ground level Ozone, Chlorofluorocarbons) and others (Volatile organic compounds, Benzene, Biological Pollutants, Asbestos, Radon); GHGs, Climate Change Pollutants. (3 hrs.)

Air Pollution in Nepal: diurnal variation of air pollution in Kathmandu and other regions, seasonal variation of air pollution **(**1 hr.)

Types and Sources of Air Pollutants: Natural and anthropogenic sources of air pollutants, ambient and indoor air pollution sources; Oxides of nitrogen, carbon-monoxide and carbon-dioxide, Hydrocarbons, Oxides of sulfur, Photochemical bi-products, Bad ozone, Particulate matter and black carbon (BC), GHGs sources and sink; air pollution in kathmandu valley; air pollution measurement history in Nepal / Kathmandu Valley. (3 hrs.)

Atmospheric Ozone: Stratospheric ozone, Sources and depletion; Meteorological processes affecting ozone; ozone measurement, total amount of ozone and Dobson, Bad ozone. (2 hrs.)

Atmospheric Aerosol: Importance and sources of tropospheric and stratospheric aerosol, atmospheric brown clouds, volcanic aerosol, desert aerosols, polar aerosol, climatic effect of aerosol, removal and sink of aerosols, aerosol as atmospheric tracers, NASA's aerosol studies. (3 hrs.)

Impacts of Air Pollution: General impacts on the biosphere, impacts on human health, impacts on structures and materials, impacts on agriculture, impacts on ecosystem (terrestrial and aquatic), impacts on climate, impacts of atmospheric brown cloud. (2 hrs.)

Effects of Atmospheric Ultraviolet Radiation: Atmospheric Radiation Distribution, UV-A, UV-B and UV-C Radiation; Effects of UV-B on human health, plants, ecosystem, biogeochemical cycles, materials, atmospheric circulation, effects of UV-A. (2 hrs.)

Dispersion Air Pollutants: Dispersion of air pollutants; plume rise and plume height; diffusion theories, examples of Dispersion models (Gaussian diffusion model, line and area source models) and Box model); atmospheric stability classes; dispersion of air pollutants in Kathmandu Valley. (2 hrs.)

Global Atmospheric Changes: Global air Circulation Model; global energy balance and radiative forcing, GHGs and Global warming in terms of historical emission of carbon-dioxide, Methane, Oxides of nitrogen, CFCs, predicted climate change from increased greenhouse gases, acid rain, possible effects of global warming; boundary layer, meteorology and air pollution relationship, atmospheric stability. (3 hrs.)

Atmospheric Chemistry: Reactions in Atmosphe**re,** Chapmann Mechanism for Ozone; Ozone Destruction Mechanism- HOx, NOx and ClOx cycles; Generalization on Photochemical Smog Formation Mechanism. (3hrs.)

Stratospheric Ozone Chemistry: Polar Stratospheric clouds (PSCs), Composition, Type I and Type II PSCs; Free Radical mechanism for ozone destruction; Ozone Hole and its chronology; Projection of future ozone change; Ozone Control Strategies; Tropospheric Ozone Formation Mechanism. (3 hrs.)

Acid Rain: Chemical composition of precipitation, sources of acids, Mechanism of Acid Rain Formation (Gas to Particle Conversion); effects of acid rain, emission of SO_2 and NO_x. (2 hrs.)

Climate Change and Transboundary Air Pollution (TAP): Introduction, Examples of TAP, Deposition and scavenging; International Treaties (UN; United Nations Framework for Climate Change (UNFCC); Initiatives of Nepal; Net Zero Concept of IPCC; IPCC obligation of Nepal, Clean development mechanism (CDM). (3hrs.)

Noise Pollution: introduction, sound pollution level and unit; frequency characteristics types of noise; effects of noise pollution; common descriptors used in noise pollution; noise monitoring; national ambient noise and occupational safety health standards; noise control measures – source, transmission path and receiver control. (2hrs.)

Water Pollution: Introduction; types of water pollution, inorganic and organic pollutants, background pollution, heavy metals, sediments, thermal pollutants, radioactive pollution; ecological aspects of water pollution and common effects; water quality parameters (physical, chemical, microbiological, radioactive); water quality criteria and standards, criteria maximum concentration (CMC) & Criterion Continuous Concentration (CCC), criteria recommendations for

priority pollutants, Non priority pollutants and organoleptic effects, human health risk, dissolved metal criteria, action level, carcinogenic criteria; national drinking water standard and water quality guidelines; overview on waste water, characteristics of municipal and industrial waste waters; wastewater reuse; tolerance limits on various type of wastewater in Nepal; fundamentals on water quality monitoring. (5hrs.)

Soil Pollution: soil processes and fundamental soil reaction; sources of soil pollution, soil pollutants and its types, bio-concentration (bio-accumulation) of heavy metals and organohalides, microplastic pollution in soil and sediment. (1 hr.)

Air Pollution Policy and Guidelines in Nepal: Air pollution policy history, strategies for air pollution control; successes and failures of air pollution control strategies; fundamentals on air pollution control measures; initiatives in global and regional air pollution control; air quality criteria, standards and guidelines, climate change policy of Nepal, air quality standards of Nepal. (5 hrs.)

Text Book

Seinfeld J. H. and Pandis S. N. (1997), Atmospheric Chemistry and Physics from air pollution to climate change, A Wiley-Inter Science Publication.

References

Masters, G M, (2004), *Introduction to Environmental Engineering and Science*, Second edition, Prentice Hall of India Pvt. Ltd., New Delhi 2004.

Murty, B.P. (2004), Environmental Meteorology, I.K. International Pvt. Ltd., New Delhi.

Pruppacher H. R., and Klett, J.D. (1997), Microphysics of Clouds and Precipitation, Kluwler Academic Publishers, Netherland,

Slade, D. H. Ed. (1974), Meteorology and Atomic Energy, U.S. Atomic Energy Commission, National Technical Service, US Dept. of Commerce, Springfield, Virginia,

Turner, D. B. (1970), Workbook of atmospheric dispersion estimates, Environmental Protection Agency Office of Air Programs, Research Triangle Park, North Carolina, 1970.

Course Title: Meteorology Practical **Credit Hrs: 2**

Course No: Hymet 506 **Lecture Hrs: 90**

Nature of the Course: Practical (Compulsory) **Full Marks: 50**

Semester: I **Pass Marks: 25**

Course Contents:

Lab 1: Differentiate complacent and sensitive ring from the given samples**.** Also indicate the normal year and extreme climatic years from the given samples**.** (3 hrs.)

Lab 2: Differentiate true ring and false ring from the given samples**.** Also indicate the normal climate year and extreme climatic years from the given samples**.** (3 hrs.)

Lab 3: From the given tree ring samples**.** Extract the information about the sampling sites**.** (3 hrs.)

Lab 4: Make the longest tree ring chronologies from the given samples and also indicate the 5 consecutive narrow rings**/**wide rings and describe climate scenarios of that consecutive period and reconstruct the at least multi-century climate from the given samples and discuss its linkage with global climatic indices. (3 hrs.)

Lab 5: Calculate the $\delta^{18}O$ and δD from the given samples. (3 hrs.)

Lab 6: Calibrate the $\delta^{18}O$ and δD values from the given raw results**.** (3 hrs.)

Lab 7: Interpret the given isotopic data sets with the climatic indices. (3 hrs.)

Lab 8: Setting up an instrument for δD and $\delta^{18}O$ measurement and Laboratory analysis. (3 hrs.)

Lab 9: Different types of thermodynamics diagram; SkewT/LogP diagram introduction and analysis. (3 hrs.)

Lab 10 and 11: To analyze Kathmandu-sounding by plotting in Skew-T/LogP from different seasons using R/NCL/Python/ or GrADS programming. (6 hrs.)

Lab 12 and 13: To find the following parameters graphically using the skew-T diagram, Also write the equation that would be used to determine the most precise values. (6 hrs.)

a. saturation point T and p values (T_{sp} and p_{sp}; give equation for T_{sp} only)
b. saturation mixing ratio
c. potential temperature

d. equivalent potential temperature
e. wet-bulb potential temperature g) dew-point temperature
f. relative humidity
g. vapor pressure
h. the temperature of a parcel that ascends adiabatically to 600 mb
i. the adiabatic mixing ratio of the parcel at 600 mb Show all work on the skew-T diagrams on the next two pages.

Lab 14 – 16: These are the specific numerical problems that will provide the detail knowledge of thermodynamics and enhance the problem-solving skills of students. The class lecture can be connected to these problems or equations and methods can be described in the practical class before starting these problems. Three classes are assigned for these problems. (9 hrs.)

a). A Carnot refrigerator has a coefficient of performance of 10. If the refrigerator's interior is to be kept at –45°C, the temperature of the refrigerator's high-temperature reservoir is most nearly to ……..

b) Helium is compressed isentropically from 1 atmosphere and 5°C to a pressure of 8 atmospheres. The ratio of specific heats for helium is 5/3. What is the final temperature of the helium?

c) The thermal efficiency of a Carnot cycle operating between 170°C and 620°C is closest to ……..

d) Superheated steam at 4.0 MPa and 275°C expands isentropically to 1.4 MPa. What is the quality factor of the resulting vapor? The data for the steam are as follows.

For 4.0 MPa, 275°C: h = 2886.2kJ/kg ; s = 6.2285kJ/kg ·K

For 1.4 MPa, dry saturated vapor: 2790.0 kJ/kg $_g$h = ; 6.4693kJ/kg K $_g$s= ·

For 1.4 MPa, saturated liquid: 830.3kJ/kg $_f$h = ; 2.2842 kJ/kg K

e) When 1.5 kg of an ideal gas (specific heat at constant volume = 0.8216 kJ/kg*K) is heated at constant volume to a final temperature of 425°C, the total entropy increase is 0.4386 kJ/K. The initial temperature of the gas is most nearly …….

f) Compressed carbon dioxide (molecular weight = 44) is kept in a full 0.5 m^3 tank at 100°C and 500 kPa. The mass of the carbon dioxide in the tank is most nearly

Lab 17: Understanding Fundamental forces. (3 hrs.)

Lab 18: To Understand balanced winds and apply it to analyze atmospheric motions. (3 hrs.)

Lab 19: To understand circulation and vorticity and its role is severe storms. (3hrs.)

Lab 20: Observe and analyze general circulation. (3hrs.)

Lab 21: To investigate the dynamics of the atmospheric boundary layer and its interactions with the surface. (3 hrs.)

Lab 22: To investigate the propagation of Rossby waves and their impact on weather in different regions. (3 hrs.)

Lab 23: To examine QG motions and the role of atmospheric waves in establishing teleconnections and influencing global weather patterns. (3 hrs.)

Lab 24: To study the dynamics of tropical systems (monsoon, cyclones) and their influence on regional weather patterns. (3 hrs.)

Lab 25: Application of NWP. (3 hrs.)

Lab 26: Measurement of SO_2, CO, CO_2, NO_x, dust particles from different air pollution sources. (3 hrs.)

Lab 27: Preparation of wind rose and pollution rose. (3 hrs.)

Lab 28: Estimation of vertical plume rise, stack height, inversion layer, mixing height (3 hrs.)

Lab 29: Pressure and temperature relationship in the lower atmosphere, temperature of a rising (or falling) parcel of air. (3 hrs.)

Lab 30: p^H, conductivity, TDS (total dissolved solids), DO (dissolved oxygen), BOD (biochemical oxygen demand), chloride, hardness, sulfate, phosphate, N-Nitrate, Nitrate, Ammonia, Iron, calcium in water sampling. (3 hrs.)

References

Clark, I., Fritz, P. (1997). Environmental isotopes in hydrology. Lewis Publisher, Boca Raton, Fla**.**

Environmental isotopes in the hydrological cycle; Principles and Applications: International Atomic Energy Agency (IAEA) and United Nations Educational, Scientific and Cultural Organization (UNESCO).

Holton J. R., (1992), An Introduction to Dynamic Meteorology, Academic Press Inc., New York.

Pruppacher, H.R. and Klett, J.D. (2010), Microphysics of Clouds and Precipitation.

Seinfeld J. H. and Pandis S. N. (1997), Atmospheric Chemistry and Physics from air pollution to climate change, A Wiley-Inter Science Publication.

Course Title: Instrumentation and Hydrology Practical **Credit Hrs: 2**

Course No: Hymet 507 (Hymet 503 & Instrumentation) **Lecture Hrs: 90**

Nature of the Course: Practical (Compulsory) **Full Marks: 50**

Semester: I **Pass Marks: 25**

Course Contents:

Lab 1: Introduction to Meteorological Station and Instruments. (3 hrs.)

Lab 2: Measurement of Temperature: Types of thermometers and thermographs, general principle, calibration, operation procedure, recording methods, correction, and general maintenance. (3 hrs.)

Lab 3: Measurement of Atmospheric Pressure: Types of barometers and barograph, general principle, calibration, operation procedure, recording methods, correction, and general maintenance (3 hrs.)

Lab 4: Measurement of Humidity: Types of hygrographs and hygrometer, general principle, calibration, operation procedure, recording methods, correction, and general maintenance. (3 hrs.)

Lab 5: Measurement of Surface Wind: Types of anemometers, general principle, calibration, operation procedure, recording methods, correction, and general maintenance. (3 hrs.)

Lab 6: Measurement of Precipitation: Types of raingauge, general principle, calibration, operation procedure, recording methods, correction, and general maintenance. (3 hrs.)

Lab 7: Measurement of Evaporation: Types of evaporimeter, general principle, calibration, operation procedure, recording methods, correction, and general maintenance. (3 hrs.)

Lab 8: Measurement of Sunshine and Intensity of Solar Radiation: Types of sunshine recorder, general principle, calibration, operation procedure, recording methods, correction, and general maintenance. (3 hrs.)

Lab 9: Cloud Observations and Measurement of Visibility: General, measurement of cloud height, measurement of cloud movement, cloud photography, measurement of visibility at day and night. (3 hrs.)

Lab 10: Radiosonde: Analysis of data collected from the launched radiosondes, Comparison with other meteorological data sources, Interpretation of atmospheric profiles and identification of key features. (3 hrs.)

Lab 11-12: Doppler Radar : Introduction to doppler radar systems, basic principles of radar operation, components of a radar system, antennas and transmitters, receivers and signal

processing, data acquisition systems, calibration procedures, radar signal processing techniques, radar operation, parameter settings, radar data collection processing and analysis, quality control and calibration of radar, Micro rain radar (measurement principles, applications, importance and limitations), ground penetrating Radar (measurement principles, application in glacier research, importance and limitations) (6 hrs.)

Lab 13: Automatic Weather Station: Introduction to automatic weather stations, AWS components and instrumentation, detailed examination of the sensors used in AWS (e.g., temperature, humidity, wind speed, wind direction, barometric pressure, precipitation), data logger and communication system, power sources and backup systems, steps involved in the installation of an AWS, safety guidelines during installation, data retrieval and communication. (3 hrs.)

Lab 14: Measurement of Aerosols: Types of instruments, principles, operational procedure, test, calibration and maintenance of instruments. (3 hrs.)

Lab 15: Introduction to Hydrometric Stations and Instruments: Overview of hydrometric measurements, Importance of accurate instrumentation in hydrology, the historical development of hydrological instruments, measurement units and standards, water level recorder calibration, and maintenance of manual and automatic stations with telemetry. (3 hrs.)

Lab 16: Current meter and ADCP: Overview of current meters, ADCP, Importance of accurate instrumentation in hydrology, the current meter and ADCP, test, calibration, and maintenance of current meter and ADCP. (3 hrs.)

Lab 17: Sediment Sampler: Overview of sediment samples, bedload and suspended sediment sampler, test, calibration, and maintenance of current meter and sediment sampler. (3 hrs.)

Lab 18: Assessment of available groundwater resources for community (3 hrs.)

Lab 19: Preparation of groundwater contour and groundwater potential mapping (3 hrs.)

Lab 20: Interpretation of constant head boundary, water flow line, and flow net (3 hrs.)

Lab 21: Analysis of pumping test data and recuperation test of the aquifer. (3 hrs.)

Lab 22: Interpretation of hydraulic head, pressure head, and related calculations. (3 hrs.)

Lab 23: Assessment of groundwater recharge, springshed, and water tower. (3 hrs.)

Lab 24: Preparation of grain size distribution curve of the given sample. (3 hrs.)

Lab 25-26: GIS application and data preparation (download topographic maps, DEMs, Satellite imagery. Georeferencing the topographical map projection system). (6 hrs.)

Lab 27-28: Watershed delineation and morphometric analysis of river basin. (6 hrs.)

Lab 29-30: Estimation of the mean arial rainfall for a given watershed using the Isohyetal and Thiessen polygon method. (6 hrs.)

References

HMSO (1956), Handbook of Meteorological Instruments (Part 1), Instrument for Surface Observation, Her Majesty's Stationery Office, London.

HMSO (1969), Observer's Handbook, Her Majesty's Stationery Office, London.

Hundson, N.W (ed.). 1993. Field Measurement of Soil Erosion and Runoff. FAO Soil Bulletin No. 68. FAO, Rome.

Raghunath, H. M. (1987) Groundwater, 2nd edition, New Age International (P) Limited, Publishers, New Delhi.

Todd, K. D. (1980), Groundwater Hydrology 2nd ed., John Wiley &Sons Inc., New York.

WMO (2006), Guide to Meteorological Instruments and Methods of Observation Preliminary 7th edition, WMO-No. 8 Secretariat of the World Meteorological Organization – Geneva – Switzerland.

WMO (2008), Volume I: Hydrology-From Measurement to Hydrological Information. Vol. I.

Course Title: Field Work **Credit Hrs: 1**

Course No: Hymet 508 **Days: 7**

Nature of the Course: Field Work (Compulsory) **Full Marks: 25**

Semester: I **Pass Marks: 12.5**

Course Contents:

This course has been designed to develop an understanding on issues pertinent to their elective papers. It helps to strengthen the field-based knowledge and widen exposure to the field conditions. For this purpose, 7 working days of field visits will be organized in the first semester (70% time in meteorology and 30% in hydrology). After completion of the fieldwork, each student has to submit his/her report for evaluation. The fieldwork is mandatory to complete the Master's in Hydrology and Meteorology. One credit (25 marks) is allocated for the fieldwork.

Courses Distribution: Second Semester

SN	Course Code	Course Name	Credits	Marks
1	Hymet.551	Synoptic and Tropical Meteorology	3	75
2	Hymet.552	Cryosphere	3	75
3	Hymet.553	Water Resources Planning and Management	3	75
4	Hymet.554	Radar and Satellite Meteorology	3	75
5	Hymet.555	Aviation Meteorology	2	50
6	Hymet.556	Micrometeorology	2	50
7	Hymet.557	Weather Analysis and Forecasting Practical	2	50
8	Hymet.558	Water Resources and Cryosphere Practical	2	50
		Total	20	500

Course Title: Synoptic and Tropical Meteorology **Credit Hrs: 3**

Course No: Hymet 551 **Lecture Hrs: 45**

Nature of the Course: Theory (Compulsory) **Full Marks: 75**

Semester: II **Pass Marks:37.5**

Course Contents:

Synoptic Meteorology: Introduction to synoptic meteorology scales of weather systems, synoptic weather observations, and surface, upper air observations; Nepal synoptic observation network, review of fundamental dynamics: force balance, continuity and scale analysis. (3 hrs.)

Global Wind System: Differences between polar, mid-latitude, and tropical weather phenomena; General circulation of the tropics – El-Niño, La Nina, El-Niño-Southern Oscillation (ENSO), trade winds and trade wind inversion, western disturbances, trough in westerlies. Flood and drought associated with ENSO. Correlation between monsoon precipitation and climate indices, Tropical and Pacific Ocean Sea surface temperature (SST) influence on monsoon, ENSO effects on the Asian monsoon, South Asian monsoon. ENSO and its effects on the global to local scale. (7 hrs.)

Middle and High Latitude Weather System: Jet streams, their classification and characteristics, Polar Front Jet, Sub Tropical Jet, Tropical Easterly Jet, low-level jet during Asian monsoon, structure, formation, maintenance and associated weather, structure, formation, and evolution of middle latitude synoptic-scale cyclones, cutoff lows, highs, and blocking. (5 hrs.)

Fronts: Frontal types and properties, kinematics of frontogenesis, dynamics of frontogenesis (frontal circulation and frontal collapse), mid- and upper-level fronts. (5 hrs.)

Baroclinic Instability: Approximations and governing equations (Anelastic equations and PV relations, Eddy baroclinic instability problem, Energetics for the Eddy atmosphere, diagnosis of ageostrophic motions in the Eddy atmosphere. (5 hrs.)

Synoptic Component of the Monsoon: Role of ITCZ on monsoon circulation, easterly waves, near-equatorial monsoon trough, trans-equatorial flow, squall lines in the monsoon area, planetary scale monsoons, corresponding elements of winter and summer monsoon, the easterly jet stream, and different components of the SW Indian monsoon. Active vs. break in monsoon (Nepal vs. India); main causes and synoptic patterns during these conditions. (5 hrs.)

Tropical Variability and Impact in Nepal: Dominant patterns of tropical systems during different seasons in South Asia and Nepal including pressure, wind, and rainfall distribution during

different seasons. Active and break situation during monsoon in Nepal, circulation patterns and moisture source conditions in extreme events in Nepal, Relationship between Nepalese summer monsoon rainfall and Southern Oscillation Index, ENSO effects on Nepalese monsoon, Definition and concept of flood, drought, indices of flood and drought, types of flood and drought. (5 hrs.)

General Mesoscale Features: Distribution of moisture during convective activities and orographic clouds, Thunderstorms (isolated/single cells, multicell, supercells), Orographic phenomena, Local-scale weather influences, Multi-scale analysis and forecasting. (5 hrs.)

Tropical Disturbances: Tropical waves, Mesoscale convective systems: brief introduction, Tropical cyclones – life cycle (structure, evolution, frequency, forecasting, etc.): seasons/months of tropical cyclones in Indian Ocean vs. other oceans, impact of tropical cyclone in Nepal (historical observations based on existing research). (5 hrs.)

Text Books:

Lackmann, Gary (2011), Midlatitude synoptic meteorology. American Meteorological Society.

Pettersen, S. (1956), Weather analysis and forecasting. Vol 1and 2, Mc-2, Mc-Graw Hill Book Company Inc., New York.

References:

Defant F. (1981), Compendium of Meteorology Vol.1 part 3 synoptic Meteorology WMO Publication No.168, Geneva.

Hess S.L. (1959), Introduction to Theoretical Meteorology, Holt Rinehart and Winston, New York.

Ramage, C.S. (1971), Monsoon Meteorology' Academic Press, New York.

Riel H. (1954), Tropical Meteorology. Mc-Graw Hill Book Company Inc, New York.

Wiin-Nielson, A. (1978), Compendium of Meteorology, Vol. I, Part 3, Synoptic Meteorology, Geneva, W.M.O. No. 364.

Course Title: Cryosphere **Credit Hrs: 3**

Course No: Hymet 552 **Lecture Hrs: 45**

Nature of the Course: Theory (Compulsory) **Full Marks: 75**

Semester: II **Pass Marks:37.5**

Course Contents:

General Introduction: Definition of cryosphere, components of cryosphere, classification and characteristics, geographical distribution, formation and development, response of cryosphere to climate change, interaction between cryosphere and other spheres, role of cryosphere in climatic system. (2 hrs.)

Alpine Geology and Environment: Tectonic plates, history of Himalayan tectonics, mineral and rocks, types of rocks, alpine landscape, mountain climate, flora and fauna, alpine ecosystem. (2 hrs.)

Snow Hydrology: Mountain hydrology, precipitation process, **s**now and ice - origin, structure and their characteristic features, snow climatology and distribution, definitions and types, snow lines and their importance, snowpack characterization (density, thermal quality, liquid water content, albedo, snow water equivalent (SWE), Snow measurement/estimation techniques (field-based and remote-sensing methods), snowmelt process. (7 hrs.)

Glaciology: Definition and scope of glaciology, global glacial chronologies and causes of glaciation; historical introduction of glacier study and its importance, glacial surface structure and its characterization, definition, formation of glaciers, types of glaciers and their classification, glacier movement, glacier mass balance (concept, methods of glacier mass balance estimation), glacial landform and features, glacial erosion, glaciers in high-mountain Asia, glacier response to climate change. (8 hrs.)

Glacial Hydrology: Glacier meltwater and runoff, subglacial hydrology, glacial lakes (proglacial, supra glacial, sub-glacial lakes, ice-dam lakes, moraine-dammed lakes); glacier hydrological systems. (3 hrs.)

Permafrost: Introduction, distribution, monitoring of permafrost, permafrost response to climate change and its impacts. (2 hrs.)

Remote Sensing and Cryosphere Monitoring: Concept, satellite imagery and data for cryosphere monitoring, in-situ measurements and instrumentation, recent advance in cryospheric research. (4 hrs.)

Snow and Glacier Melt Modeling: Concept, physics of snow melt, heat budget and radiation, temperature index model, energy balance model. (4 hrs.)

Cryospheric Hazards: Snow/ice avalanche, Glacial Lake and its Outburst Flood-GLOFs (definition, mechanisms, incidences/events, history), GLOF in the Nepal Himalaya, introduction: glacier, moraine, debris, glacier lakes: definition, types, evolution records and database of GLOF in Nepal, glacier lake outburst floods (GLOF), estimation of floods (GLOF) and possible damages, mitigation system and process for GLOF in Nepal. (5 hrs.)

Cryosphere and Society: Cryosphere services; supporting, provisioning, regulation and culture (2hrs.)

Global Warming and its Impacts: Snowmelt process, high rate of ice melt, circulation and environmental impacts, Impact of global warming on snow and glaciers. (2 hrs.)

Flow Laws of Glacier Ice: Flow law of polycrystalline ice, general flow law of ice, glacier flow laws in parallel and nonparallel intermediate surfaces, velocities in laminar flow and nonlaminar flow, basal sliding in glaciers: Weertman's theory, velocities in extending and compressive flow in glacier ice, application and modification of theoretical laws in glacier flow. (4hrs.)

Text Books:

Dewalle, D. R and Rango A., Principles of snow hydrology, Cambridge University Press

Paterson, WSB, The Physics of Glaciers, 2nd and 3rd Edition, Elsevier Science Ltd. Kingster, England, 1994.

References:

Glacial Lake and its Outburst Flood in the Nepal Himalaya, Tomomi Yamada-Institute of Low Temperature Sciences, Hokkaido University, Sapporo, Japan. Data Centre for Glacier Research Japanese Society of Snow and Ice, Chiyoda-ku, Tokyo 102-0071, Japan.

Glacier and Glaciation, Douglass I. Benn and J. A. E. Davis (1998), Dept. of Geography and Topo

Impact of climate change on Himalayan glaciers and glacial lakes; Case studies on GLOFs and associated hazards in Nepal and Bhutan, ICIMOD.

Len, M. H. J. (1992), Glaciers, Cambridge University.

Science, University of Glasgow, UK

Snow and Ice Science in Hydrology, Editors: M. Nakawo and N. Hayakaya, Asst. Editors: L.E. Goodrich, International Hydrological Program (IHP), Institute for Hydrospheric-Atmospheric Sciences, Nagoya University, IHAS, UNESCO.

Course Title: Water Resources Planning and Management **Credit Hrs: 3**

Course No: Hymet 553 **Lecture Hrs: 45**

Nature of the Course: Theory (Compulsory) **Full Marks: 75**

Semester: II **Pass Marks:37.5**

Course Contents:

Introduction: Types of water resources, major /continental-scale river basins, national and global use of water, significance of planning for water resources development, history of water resources planning and management in Nepal. (2 hrs.)

Planning for Water Resources Development: Levels of water resources planning, phases, objectives**,** steps involved in planning the water resources project, project formulation and evaluation, function and objectives of single/multipurpose projects, requirement of various objectives in multipurpose projects, cost allocations to various uses in multipurpose project, the socio-environmental impact of water resources project, concept of integrated water resources management (IWRM), principles of IWRM, benefit of IWRM to different sectors, public sector institutions, gender and water, gender and water technology, policies and water rights, water-related conflicts, water users groups and conflicts on sharing of water sources. (3 hrs.)

Reservoir and Dam: General design factors, storage capacity determination, live storage capacity, Mass curve, Flood storage, Dead storage, Reservoir silting, spillway size, sediment control/handling, Reservoir operation fundamentals, optimization of reservoir, operation of reservoir with conventional rule, Operation of reservoir with single rule curve, Reservoir operation with zoning or partitioning, Ideal reservoir operation for flood control, Operation procedure of multipurpose reservoir, Reservoir operation from practical considerations, Based on annual storage capacity to the annual runoff, Based on regulation of reservoirs, Spillway gate operations schedules, Operation to ensure maximum and minimum flow, types and classification of dam, selection of dam, stability analyses of dam, seepage in dam, dam safety, spillway, essential of spillway, component and types of spillway, spillway gates, energy dissipation below spillway, reservoir economics, socio-environmental impact of dam. (5 hrs.)

Hydroelectric Power and Energy: Basic concept of energy and electricity, sources of energy production, hydroelectric power and energy, definition-firm power, secondary power, installed capacity, dependable capacity, capacity factor, utilization factor, plant factor, power factor,

average load, baseload, peak load, load distribution, classification of hydroelectric plant, advances of hydroelectricity, essential data for hydroelectric study, component of hydroelectric plants, Preliminary studies; site selections; suitability; of different structures, hydrological investigations for feasibility and detail design level; planning considerations for changes in head, determination of number of units and plant operation strategy; overall layout, sediment handling in hydroelectric project, concept of energy economics, power tariff and trade, Public, Legal and Policy Regimes in Hydroelectricity Development. (5 hrs.)

Irrigation and Drainage: Soil profile, physical properties of soil, soil-water-plant relationship, crop period, field capacity, farming practices, 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, duty and delta, irrigation efficiency, method and system of irrigation, impact of irrigation on hydrological regime, waterlogging; waterlogging ill effect, antiwater logging measures, land reclamation, land drainage, operation, maintenance and cost recovery, Issues of water pricing and irrigation service fees legal and institutional aspects; operation of irrigation systems; reasons and consequences of poor operation; irrigation deliveries; water distribution methods and procedures, sediment handling in irrigation project, specific operation procedures, water rights and conflicts in irrigation, gender dimension of irrigation, irrigation governance, indigenous technology, private sector involvement in irrigation, modernization of irrigation infrastructure and irrigation management practice in Nepal. (5 hrs.)

Water Supply and Sanitation: Water needs, water supply, water consumption, water demand, types of water distribution system, drinking water supply and sanitation, water availability, rural water supply and sanitation, method of supplying water, municipal storm drainage system, hydrant, waste-water and its type**,** health aspect regarding water-related diseases, urban water supply and sanitation, problems of adequate supply and disposition of used water, problems for supply of water, conjunctive use of ground and surface water, quality requirement of water supply, methods of purification, river health, gender equality and social inclusion, participatory processes in water supply and sanitation, Nepal national water supply and sanitation sector policy. (5 hrs.)

River Training, Flood Hazard Mapping, Navigation and Recreation: Introduction, hydrological extreme analysis**,** objective of river training principle of river training works, classification of river training works, river training structures, planning for river training works,

bank protection, embankment, spur, artificial cutoff, river diversion, socio-economic impact of river training works, inundation, water debates between India and Nepal, requirement of navigation water way, navigation dam, navigation locks, aqueduct, water transport in Nepal; practice and possibility, white water rafting, safety guidelines for navigation. (5 hrs.)

Urban Hydrology: Climate modifications, catchment response modifications, urban development planning, drainage design (impervious areas, motorways and airports, small urban catchments), flood protection, conservation, disposal of surface water, stormwater management model, vulnerability to water related infrastructure, climate change vulnerability assessment of water structures, causes of urban flood in Nepal, urban floods and its mitigation measures. (4 hrs.)

Economics of Water Resources Management: Water and economics, socio-economy of river basin planning, steps involved in engineering economy study, benefit cost ratio, net present value, cost estimating, internal rate of return, annual cost and benefit, objective function for water use, cash flow diagrams, interest and taxes, economic decision components, time value of money, private investment in water resources projects, value of water, the role of water in public-private-partnership, cost recovery, water pricing, governance of water. (4 hrs.)

Environmental Impact Assessment Study: Concepts of EIA/IEE, requirements of EIA/IEE in water sector development projects, environmental impact of water resources projects; hydrological and water quality impacts, ecological and biological impacts, settlement-social-cultural impacts, landscape changes, human health impacts, livelihood impacts, EIA /IEE methodologies. (3 hrs.)

Water Policy: Significance of water policy in water resources development and management, water resources policy, hydropower, irrigation and water supply policies, water-induced disaster management policy, water transport policy, and recreation policy. Water pricing policy, international water treaties, water resources-related laws, conflicts between federal, provincial, and local governments, riparian countries, riparian water rights, issues of upstream and downstream benefit, Indo-Nepal water resources treaties, world commission of dam and water politics. (4 hrs.)

Text Books

Mays, W.L. (2011), Water Resources Engineering 2nd edition, John Wiley & Sons, Inc. USA.

Linsley, R.K. and Franzini, J.B. (1972), Water-Resources Engineering. 2nd edition, McGraw-Hill Book Company, New York.

References

Chow, V.T. Maidment, D.R. and Mays, L.W. (1988), Applied Hydrology. McGraw-Hill International Edition, Civil Engineering Series, New York.

Dingman, S.L (1994), Physical Hydrology, Prentice Hall New Jersey.

Dixit, A. (2002), Basic Water Science Nepal Water Conservation Foundation, Kathmandu, Nepal.

Patra, K.C. (2002), Hydrology and Water Resources Engineering, First reprint, Narosa Publishing House, New Delhi.

Raghunath, H. M. (1987) Groundwater, 2nd edition, New Age International (P) Limited, Publishers, New Delhi.

Raghunath, H. M. (2006) Hydrology Principles, Analysis, Design, 2nd edition, New Age International (P) Limited, Publishers, New Delhi.

Reddy, P. J. (2011) A Text Book of Hydrology, 3rd edition, Laxmi Publications P. Ltd., New Delhi, India.

Subramanayam, K. (2008) Engineering Hydrology, 3rd edition, TATA McGraw Hills Publications Ltd., New Delhi.

Todd, K. D. (1980). Groundwater Hydrology 2nd edition, John Wiley &Sons Inc., New York.

Course Title: Radar and Satellite Meteorology **Credit Hrs: 3**

Course No: Hymet 554 **Lecture Hrs: 45**

Nature of the Course: Theory (Compulsory) **Full Marks: 75**

Semester: II **Pass Marks:37.5**

Course Contents:

Introduction to Remote Sensing: History of radar meteorology, radar basics, types of radar (different bands of radar) and application; advantages of different bands, radars used in aviation, weather radar. (3 hrs.)

Radar Equation, Radar Reflectivity, Rainfall Estimation, Development of the Z-R Relationship: Point target radar equation, spherical targets, standard targets, Birds, Aircraft, buildings, Radar equations – in terms of σ, D and z, Z-R relationship and rainfall rate estimation, challenges in precipitation estimation using radar, applications in forecasting. (6 hrs.)

Radar Scanning Strategy/Patterns and Doppler Radar: PPI, RHI, Volume scanning pattern vs. base pattern, Impact of meteorological (Thunderstorms, wind shear, turbulence and fronts, outflow boundaries) and non-meteorological (range, signal-to-noise ratio, ground clutter, and anomalous propagation) factors on radar measurements. (6 hrs.)

Doppler and Dual-polarization Radar: Doppler radar principles and measurements, Doppler velocity – block diagram of Doppler radar, maximum unambiguous velocity, maximum unambiguous range, Specific differential phase (Kdp), Differential reflectivity (Zdr), Correlation coefficient (ρhv), Linear depolarization ratio (LDR), Application of Dual-Polarization radar (Improved rainfall estimation and hydrological applications, Hail detection and characterization, Identification of precipitation types e.g., rain vs. snow). (12 hrs.)

Radar Data Interpretation and Case Studies: Interpretation of radar imagery and products, Case studies of significant weather events, use of radar data in weather forecasting, hands-on exercises, and practical applications. (6 hrs.)

Satellite Meteorology: Satellite basics, Satellite orbits, Radiation theory, Geostationary vs. polar orbital satellite, best satellites for Nepal (India and China), Himawari, Visible, infrared and water vapor image interpretation, identifying cloud types using satellite data, Application of satellite data to monitor forest fires and air pollution (MODIS, Sentinel and VIIRS). (12 hrs.)

Text Books

Rinehart, R.E. (2010). Radar for meteorologists. ISBN-13: 978-0965800204

Kelkar, R. R. (2007). Satellite Meteorology. ISBN-13: 978-9352301270

Course Title: Aviation Meteorology **Credit Hrs: 2**

Course No: Hymet 555 **Lecture Hrs: 30**

Nature of the Course: Theory (Compulsory) **Full Marks: 50**

Semester: II **Pass Marks:25**

Course Contents:

Fog: Fog formation mechanisms, common locations, weather conditions related to these fogs, Radiation fog, Advection fog, Upslope fog, Steam fog, Frontal fog, and Ice fog. (2 hrs.)

Visibility: Factors affecting visibility, large-scale weather conditions vs. local weather conditions responsible for the reduced visibility, Types of visibility, Prevailing (Horizontal or Ground) visibility, Sector Visibilities, Flight Visibility. Slant range visibility, Vertical visibility, Runway Visual Range (RVR). Weather causing reduced visibility (Smoke, Smog, Blowing dust/sand, Blowing snow and Drifting snow, Whiteout (or Brownout), Glare, Black Hole and Volcanic Ash). (2 hrs.)

Icing: Causes of icing, Consequences of Icing. (1 hr.)

Turbulence: Intensity of turbulence, Different indices to evaluate the turbulence including wind shear at different level (radiosonde analysis), hodograph etc. Types of Turbulence – Mechanical turbulence, Frontal turbulence, Orographic turbulence, Wind shear, Turbulence from Virga, and Clear Air Turbulence. (3 hrs.)

Terrain Induced Flow: Dynamic modification – Planetary-scale effects, Synoptic-scale effects, blocking effects and barrier winds (lee cyclogenesis); Thermally induced winds – slope winds, mountain and valley winds, Flows through gaps, channel and passes; Mountain Waves – Main Causes of Mountain waves, Required conditions for mountain waves, Downslope windstorm, Rotor clouds. (5 hrs.)

Mountain Winds: Daily cycle of along-valley winds and temperature structure, Modification of diurnal mountain winds by variation in the surface budget, Disturbances of the daily cycle by large scale flows. (2 hrs.)

METARs: METAR Structure; Station Identifier, Date and time, AUTO or COR, Wind, Prevailing visibility, RVR, Present weather, Sky condition, temperature and dewpoint, Altimeter setting, SPECI Criteria. (2 hrs.)

TAFs: TAF Creators, TAF Structure – ICAO Airport Identifier, Valid time (issue and valid periods), Surface wind, Low level wind shear, Prevailing visibility, Significant weather and sky condition, Change Groups: (From, Becoming, Temporary and Probability), Amendments. (2 hrs.)

Graphical Forecasts for Aviation: Issue time and Valid times, Clouds and weather chart, Areas of turbulence. (2 hrs.)

SEGMETs and AIRMETs: Structure of SIGMET, Convective SIGMETs, Conditions Warranting n AIRMET, Graphical AIRMET. (1 hr.)

ENROUTE: Overview of the weather for both airports, existing and forecast weather along the route, Example of ENROUTE. (1 hr.)

Upper-Air Wind and Temperature: Map of temperature and wind from global forecast model products. (1 hr.)

Altimetry: Different types of altitude, How to set the altimeter, Altimeter error, Humidity and temperature effects on density altitude and engine performance, Altimetry calculation during different scenarios. (3 hrs.)

Significant Weather (SIGWX) Charts: Surface Prognostic Charts, Low-, Mid-, and High- level SIGWX charts. (1 hr.)

Weather Radar: How radar output can be utilized for aviation weather monitoring and forecasting. (1 hr.)

Satellite-Based Weather: Different satellite images to find the clouds, thunderstorms, fog, smoke, dust storm. (1 hr.)

References

Pilot Weather from Solo to the Airlines by Dough Morris and Scott Dennstaedt

Whiteman, C.D. (2000). Mountain Meteorology: fundamentals and applications. Oxford University Press.

Barry, R.G., 2008 (or 2013). Mountain weather and climate. Routledge.

Course Title: Micrometeorology **Credit Hrs: 2**

Course No: Hymet 556 **Lecture Hrs: 30**

Nature of the Course: Theory (Compulsory) **Full Marks: 50**

Semester: II **Pass Marks: 25**

Earth-Atmosphere Boundary Layer and Scope of Micrometeorology: Introduction of micrometeorology and microclimatology, surface and air temperature variation, energy balance parameter, derivation of heat and temperature in the earth's surface. (3 hrs.)

Electromagnetic Radiations Short Wave and Long Wave Radiation on Earth's Surface: Spectrum of wavelength region of electron, mean and turbulent parts, estimation and measurement process, radiation balance near the surface. (3 hrs.)

Air Temperature and Humidity in the PBL: Air and surface temperature near the earth's surface, factors influencing air temperature and humidity, basic thermodynamic relations and the energy equation, local and nonlocal concepts of static stability, mixed layers, mixing layers and inversions, vertical temperature and humidity profiles, diurnal variations. (3 hrs.)

Soil Temperature, Atmospheric Lapse Rates; Moisture & Evaporation: Air and soil temperature, temporal & spatial variation, thermal properties of soils, theory of soil heat transfer, thermal wave propagation in soils, mixing ratios and its dynamic variation. (3 hrs.)

Heat Transformation Process on Soil (Earth's) Surface: Heat and temperature transfer in various surface, mass flux, moisture flux, heat flux and their relationship to water equivalent, relationship between mass flex & energy flex, heat conduction and transformation process in various surfaces, the Fourier heat conduction equation, its derivation and application. (3 hrs.)

Wind Distribution in the PBL: Dimension analysis and similarity theory, Viscosity, shearing stress & mean wind, Horizontal & vertical wind system, Estimation and use of friction wind velocity. (3 hrs.)

Turbulence over Homogenous Surface: Definitions and example of various turbulence, Spectrum of turbulence, Shear stress, eddy fluctuation & estimation, The Kolmogorov similarity theory & its use. (3 hrs.)

Turbulent Transfer of Heat from Homogenous Surface: Radiation balance of snow & ice surface, snow surface temperature wind profile & vertical heat transformation, heat flex & heat

storage within snow and ice cover, heat transformation within a plant cover, moisture, latent heat transfer & its effect. (3 hrs.)

Air Mass Systems Over Land & Water Bodies: Over bare ground, dry-wet surface, effect of Fences & Hedges, over snow, glaciers & high mountains, over a city, valley, ocean & lakes. (3 hrs.)

Energy Balance Estimation Process: Purpose of research, data requirements, equations, estimations of various parameters (temperature, moisture etc), equivalent conversation of heat flux in terms of mass flux a water depth flex to understand mass balance for a particular purpose for research theme. (3 hrs.)

Text Book

Munn, R.E. (1966), Descriptive Micrometeorology, Academic Press New York.

References

Boundary Layer Meteorology Introduction to Micrometeorology (2nd ed)

S Pal Arya, Introduction of Micrometeorology, 2nd edition.

Course Title: Weather Analysis and Forecasting Practical **Credit Hrs: 2**

Course No: Hymet 557 **Lecture Hrs: 90**

Nature of the Course: Practical (Compulsory) **Full Marks: 50**

Semester: II **Pass Marks:25**

Course Contents:

Lab 1: Surface map analysis and contouring: To analyze the map, put the right location of the fronts and then find the associated weather. (3 hrs.)

Lab 2: Upper-Air map analysis and contouring: To relate the surface and upper-level map; Contour the upper-level map (500 mb and 200 mb). (3 hrs.)

Lab 3: Map analysis of summer monsoon. (3 hrs.)

Lab 4: Map analysis of winter monsoon/western disturbances. (3 hrs.)

Lab 5: Relationship between rainfall and SOI in Extreme events In Nepal. (3 hrs.)

Lab 6: Find a strong El Nino and La Nina year. Make the SST plots for these two years. Also, plot the summer monsoon precipitation in South Asia and compare the precipitation for Nepal during those two years. (3 hrs.)

Lab 7: Mid-latitude cyclone Analysis: What are the conditions for the formation of cyclones? Compare the pressure levels maps (850, 700, 500 and 200 mb). Draw the front lines. (3 hrs.)

Lab 8-9: Weather Radar analysis. (3 hrs.)

Lab 10: Hazardous impact of flood and drought. (3 hrs.)

Lab11: Climatic vulnerability monitoring in Kathmandu. (3 hrs.)

Lab 12: Climate (drought/flood) risk mapping of Nepal and also A) Station wise, b) Region wise, C) Basin wise, D) Country wise. (3 hrs.)

Lab 13-14: Forecasting Mountain wave turbulence for aviation using sounding and weather maps; how mountain weather creates severe weather including downslope windstorms, rotor clouds, icing, and turbulence. What are the conditions that favor the severe weather over the mountains (vertical profile from Skew-T, different level weather charts, synoptic conditions etc.). (6 hrs.)

Lab 15: Forecasting clear air turbulence. (3 hrs)

Calculate the turbulence indices (Ellrod Index, Richardson Number, Absolute Vorticity Values, Turbulent Kinetic Energy (TKE), and/or Bulk Shear)

Use the given upper-level map to Identify Areas of CAT (All in-depth sections)

Confirm Likely Areas of Turbulence with Indices and Products

Lab 16: Identify precipitation type and freezing layers using the given different Skew-T. (3 hrs.)

Lab 17 GrADS basics, data type and format, input/output, installation, built-in functions, and default data sets. (3 hrs.)

Lab 18 Display and plots using basic commands (a) Vector Plot (b) Contour plot C) Shaded plot. (3 hrs.)

Lab 19 NCEP Reanalysis data analysis at different vertical levels: specific humidity, sea level pressure, lines, zonal and meridional wind. (3 hrs.)

Lab 20 Time series analysis: temporal mean, moving average, standard deviation, coefficient of variation, and making climatology and anomaly from 30 yrs data period. (3 hrs.)

Lab 21 GrADS scripting language and its applications. (3 hrs.)

Lab 22: Radar images of different variables interpretations. (3 hrs.)

Lab 23: Extreme precipitation analysis: Radar images of melting layer, convection and high-intensity precipitation. (3 hrs.)

Lab 24: Doppler velocity and radial velocity analysis and interpretation of the weather. (3 hrs.)

Lab 25: Satellite principle, measurements and output. (3 hrs.)

Lab 26: Satellite data analysis and interpretation for different clouds. (3 hrs.)

Lab 27: Satellite products for the pollution, dust and smoke. (3 hrs.)

Lab 28: Satellite products for the wildfires. (3 hrs.)

Lab 29: Utilization of satellite and radar products in nowcasting. (3 hrs.)

Lab 30: Combining the observation, forecast, radar and satellite products to finalize the nowcasting. (3 hrs.)

References:

Hess S.L. (1959), Introduction to Theoretical Meteorology, Holt Rinehart and Winston, New York.

Pettersen, S. (1956), Weather analysis and forecasting. Vol 1and 2, Mc-2, Mc-Graw Hill Book Company Inc., New York.

Rinehart, R.E. (2010). Radar for Meteorologists. ISBN-13: 978-0965800204.

Whiteman, C.D. (2000). Mountain Meteorology: Fundamentals and Applications. Oxford University Press.

Course Title: Water Resources, and Cryosphere Practical	**Credit Hrs: 2**
Course No: Hymet 558	**Lecture Hrs: 90**
Nature of the Course: Practical (Compulsory)	**Full Marks: 50**
Semester: II	**Pass Marks:25**

Course Contents:

Lab 1: Construction of reservoir area-volume-storage capacity for a proposed reservoir. (3 hrs.)
Lab 2: Analysis of hydrological extremes. (3 hrs.)
Lab 3: Computation of sediment duration curve and sediment transport of the river. (3 hrs.)
Lab 4: Preparation of energy table for hydropower project. (3 hrs.)
Lab 5: Determination of crop water requirement for irrigation project. (3 hrs.)
Lab 6: Municipal and Rural water supply analysis. (3 hrs.)
Lab 7: Vulnerability assessment of water infrastructure. (3 hrs.)
Lab 8-10: Hydrological modeling of the river basin from lump model. (12 hrs.)
Lab 11-12: Prepare a feasibility report of a given water resource project. (9 hrs.)
Lab 13-15: Review water resources projects (hydropower, irrigation & water supply). (9 hrs.)
Lab 16: Calculation of temperature gradient and lapse rate. (3 hrs.)
Lab 17: Time series analysis of meteorological data of High-mountain region (3 hrs.)
Lab 18: Analysis of the diurnal cycle of meteorological parameters in high mountains. (3 hrs.)
Lab 19: Analysis of altitudinal variation of precipitation. (3 hrs.)
Lab 20: Calculation of vapor pressure and its gradients. (3 hrs.)
Lab 21: Glaciological mass balance at point scale using stake data. (3 hrs.)
Lab 22: Point to glacier-wide mass balance (glaciological method). (3 hrs.)
Lab 23-24: Mapping glacial features in open-source tools. (6 hrs.)
Lab 25: Modeling glacier melt using the Degree Day model. (3 hrs.)
Lab 26-28: Delineation of clean, debris-covered Glacier mapping of given watershed. (9 hrs.)
Lab 29-30: Preparation of Geo-statistical Database of Glaciers. (3 hrs.)

References:

Paterson, WSB, The Physics of Glaciers, 2nd and 3rd Edition, Elsevier Science Ltd. Kingster, England, 1994.

Patra, K.C. (2002), Hydrology and Water Resources Engineering, First reprint, Narosa Publishing House, New Delhi.

Raghunath, H. M. (2006) Hydrology Principles, Analysis, Design, 2nd edition, New Age International (P) Limited, Publishers, New Delhi.

Reddy, P. J. (2011) A Text Book of Hydrology, 3rd edition, Laxmi Publications P. Ltd., New Delhi, India.

Subramanayam, K. (2008) Engineering Hydrology, 3rd edition, TATA McGraw Hills Publications Ltd., New Delhi.

Courses Distribution: Third Semester (Compulsory)

SN	Course Code	Course Name	Credits	Marks
1	Hymet.601	Climate Change, Natural Disasters, and Climate Resilience	2	50
2	Hymet.602	Seminar	1	25
3	Hymet.603	Internship	1	25
4	Hymet.604	Project/Community Works, Field Work	2	50
5		Elective I	2	50
6		Elective II	2	50
7		Elective III	2	50
8		Elective Practical	2	50
		Total	14	350

Course Title: Climate Change, Natural Disasters and Climate Resilience **Credit Hrs: 2**
Course No: Hymet 601 **Lecture Hrs: 30**
Nature of the Course: Theory (Compulsory) **Full Marks: 50**
Semester: III **Pass Marks:25**

Course Content:

Introduction to Disaster: Hazard, risk, exposure, and vulnerability; natural and anthropogenic hazards; risk assessment; parameters of vulnerability; vulnerability analysis; disasters: natural and manmade disasters, global environmental problems (Climate change, Biodiversity loss, Desertification, Global water crisis), linkages between climate change and natural disaster, Definition and classification of natural disasters, historical perspectives and trends, factors contributing to disaster vulnerability, damage estimation. (2 hrs.)

Geological Disaster: Earthquakes and Tsunamis, seismic hazard analysis, site response analysis, liquefaction, earthquake-induced landslide, emergency response and recovery, earthquake protection strategies, earthquake resistance of structures, risk and vulnerability assessment, geological disasters, volcanic eruptions, Landslides and avalanches. (3 hrs.)

Technological Disasters and Industrial Accidents, Rural and Urban Fire: Nuclear accidents, chemical spills and toxic releases, and industrial explosions and structural failures, rural and urban fire management, fire dynamics and behavior, fire prevention and suppression techniques, wildfire management and urban fire safety, infrastructure failures. (3 hrs.)

Wildfires: Classification of wildfires, fire behavior, fire triangle: fuel, weather, and topography, fire spread patterns and modeling, wildfire causes, meteorological factors influencing fire behavior, fire weather indices and fire danger rating systems, the role of wind, temperature, humidity, and atmospheric stability, wildfire prevention and mitigation, vegetation management and fuel reduction strategies, community outreach and public education programs, wildfire suppression and incident management, historical overview and major wildfire events firefighting techniques and equipment. (3 hrs.)

Hydro-climatic Disaster: Introduction to hydro-climatic disasters, definition and classification of hydro-climatic disasters, causes and triggers of hydro-climatic disasters, impacts and consequences of hydro-climatic disasters, overview of disaster risk reduction and management, floods: causes, types, and characteristics, droughts: causes, indicators, and impacts, storm surges and coastal hazards, landslides and debris flows, GLOF/ LDOF, tropical cyclones , heatwaves

and extreme temperatures, risk assessment and vulnerability analysis, impacts on human populations and communities, economic losses and infrastructure damage, Social vulnerability and resilience, land-use planning and zoning, Climate change adaptation measures, Structural and non-structural measures, historical hydro-climatic disasters, case studies from different regions/countries, successful strategies and lessons learned, policy and Governance. (3 hrs.)

Policies and Legal Framework of DRM: The federal, provincial, district as well as local government in disaster risk management, emergency operation center, standard operating procedures, mainstreaming of disaster risk management in the periodic plans and programs of local government in Nepal, acquisition of land for pre-disaster and post-disaster situations and the concerned legal tools, Equality to the law, Concept of Law, Legislation, Ordinance, Bill, Act, Regulations and Bye-Laws, Importance of Law and its relationship to Disaster Risk Management, Nepal Constitution, Concept and Contents, Provision regarding disaster risk Management. (3 hrs.)

Community-Based Disaster Risk Management: Introduction to community, livelihood, and Capacity of different social groups, Participation theory, Importance of Community-based Disaster Risk Management and processes, understanding social learning and rapport building with the communities, Importance of Community based Disaster Risk Management and processes, Participatory Disaster Risk Assessment and Management Planning, Participatory monitoring and evaluation, Disaster Risk Communication at the community level. (3 hrs.)

Disaster Risk Mitigation Technology and Humanitarian Assistance: Definition, concept, importance, guiding principles, tools, approaches, strategies, sustainable development, sustainable land use planning, team work, conflict resolution, technology, technological society and environment, emerging technologies in disaster mitigation, remote sensing, gis, disaster mapping, aerial photography, land use zoning, emergency communication, wireless and radio, ham radio, worst scenario analysis, emergency operations center, cost benefit analysis, hazard specific technologies (flood, landslide, earthquake, fire etc). (3 hrs.)

Post Disaster Assessment and Response Planning: Natural Disasters and Emergencies, Type and level of impact, UNHCR Principles & international law and guidelines on Humanitarian assistance, Humanitarian Relief System, United Nations Disaster Assessment and Coordination System, Declarations of Emergency and calls for assistance, Agencies and coordination mechanism, Emergency response , early recovery and reconstruction phase, Search and Rescue, Coordination and cooperation, role and responsibilities Donor & UN, Agencies, federal,

provincial and local governments, I/NGOs CBOs, Case studies, Assessment and response planning of Major, medium and creping disaster (Aceh, Haiti, west Sumatra, Pakistan etc). (3 hrs.)

Socio-economic, Impacts, Disaster Risk Reduction and Resilience: Concepts and principles of disaster risk reduction, community-based disaster management, climate change adaptation and resilience, loss of life and injuries, damage to infrastructure and property, environmental degradation and ecological impacts, emerging trends and future challenges, climate change and its impact on natural disasters, technological advancements in disaster management, ethical considerations in disaster response and recovery. (3 hrs.)

Disasters in Nepal: Hydro-meteorological, technological disasters, industrial accidents, geological, epidemics, rural and urban fire disasters in Nepal, temporal and spatial distribution of disasters in ecological and physiographic zones of Nepal; documentation of disaster events in Nepal; stakeholders for Disaster Risk Reduction (DRR) in Nepal. (1 hr.)

References

Bankoff, G., Frerks, G., and Hilhorst, D. (2004). Maping vulnerability, disasters, development and people. Earthscan, London.

Bryant, E. (2005). Natural hazards. Cambridge University Press, Cambridge.

GoN. (2008). National strategy for disaster risk management. Government of Nepal, Kathmandu.

Goyal, M.N, Gupta, A.K., Gupta, A. (ed.) (2006). Disaster Resilience and Green Growth: Hydro-Meteorological Extremes and Disaster, Springer Nature, Singapore.

Hygo Framework for Action: building the resilience of nations and communities. (2005). The World Conference on Disaster Reduction, 18 to 22 January 2005, UNISDR, Geneva.

Kreimer, A. and Arnold, M. (2000). Managing disaster risk in emerging economics. World Bank, Washington DC.

Paron, P., Shroder, J. F., Baldassarre, G. Di (2023), Hydro-Meteorological Hazards, Risks, and Disasters, 2nd Edition. Elsevier.

Wishner, B., Blaikie, P., Cannon, T., and Davis, I. (2004). At risk: natural hazards, people's vulnerability and disasters. Routledge, Oxon.

Course Title: Seminar **Credit Hr: 1**

Course No: Hymet 602 **Lecture Hrs: 15**

Nature of the Course: Seminar (Compulsory) **Full Marks: 25**

Semester: III **Pass Marks:12.5**

Students must give one seminar to the department related to his/her area of specialization.

Course Contents:
Students should learn different research tools available for the research of hydrology and meteorology. Students should thoroughly understand the application of these tools by consulting three research papers of his/her interests. Students should finally present his/her understanding of tools and research papers in the class in front of all faculties in the department. Students will submit a seminar report to the department for which one credit (25 marks) will be allocated.

Course Title: Internship **Credit Hrs: 1**

Course No: Hymet 603 **Working Days: 15**

Nature of the Course: Internship (Compulsory) **Full Marks: 25**

Semester: III **Pass Marks:12.5**

Students must complete at least two weeks of internship at a relevant government/non-government/international organization. They will submit a report to the department for which one credit (25 marks) will be allocated.

Course Title: Project/Community Works, Field Work **Credit Hrs: 2**

Course No: Hymet 604 **Working Days: 22**

Nature of the Course: Fieldworks (Compulsory) **Full Marks: 50**

Semester: III **Pass Marks:25**

Students must complete at least two weeks of project/community work related to his/her area of specialization. They will submit a report to the department for which one credit (25 marks) will be allocated.

Students must complete at least 7 working days of fieldwork related to his/her area of specialization. They will submit a report to the department for which one credit (25 marks) will be allocated.

Courses Distribution: Third Semester (Elective- Climate Science Stream)

SN	Course Code	Course Name	Credits	Marks
1	Hymet.611	Climate Modeling	2	50
2	Hymet.612	Applied Climate Science	2	50
3	Hymet.613	Climate Change Mitigation, Adaptation, and Resilience	2	50
4	Hymet.614	Applied Climatology and Climate Modeling Practical	2	50
		Total	8	200

Course Title: Climate Modeling **Credit hrs: 2**

Course No: Hymet 611 **Lecture hrs: 30**

Nature of the Course: Theory (Elective) **Full Marks: 50**

Semester: III **Pass Marks:25**

Course contents:

Applied Climatology: Nature and scope of Applied Climatology: Atmospheric concern and awareness; Climate and the physical environment; Climate and biological environment; Climate and industrial and commercial activities; Climate and transport services. (5 hrs.)

Climate System: Description of the climate system and its components; The atmosphere; The ocean; The cryosphere; The land surface and the terrestrial biosphere. (5 hrs.)

Climate Models: Basics of models, primitive equations and their simplification; Concept of Parameterizations, time-stepping and resolution; Framework and process of model simulations; Types of Models; Uncertainties and sensitivity. (5 hrs.)

Components of Climate Model: Atmosphere; Ocean; Sea ice; Land surface; Marine biogeochemistry; Ice sheets. (3 hrs.)

Climate System Response: The response of the climate system to a perturbation; Climate forcing and climate response; Direct physical feedback; Geochemical, biogeochemical and biogeophysical feedback. (4 hrs.)

Future Climate Change: Emission scenarios; The purpose of the scenarios and scenario development; Special Report on Emission Scenarios (SRES); Representative concentration pathways (RCPs) in CMIP5 vs. Shared Socio-economic Pathways (SSPs) in CMIP6; Climate projections for the 21st century; Changes in global mean surface temperature; The spatial distribution of surface temperature and precipitation changes; Changes in the ocean and sea ice. (8 hrs.)

Text Books:

Coiffier, J., Fundamentals of Numerical Weather Prediction, Cambridge University press, 2012

Loutre and V. Zunz, 2010. Introduction to climate dynamics and climate modeling.

Randall, D., An Introduction to Numerical Modeling of the Atmosphere, 2009.

Course Title: Applied Climate Science **Credit Hrs: 2**

Course No: Hymet 612 **Lecture Hrs: 30**

Nature of the Course: Theory (Elective) **Full Marks: 50**

Semester: III **Pass Marks:25**

Course Contents:

Nature and scope of Applied Climatology: Atmospheric concern and awareness; Climate and the physical environment; Climate and biological environment; Climate and industrial and commercial activities; Climate and transport services. (3 hrs.)

Application of Climate Science: Climate and human comfort; Climate and town planning, architecture and building; Climate and tourism; Urban climate and global environment change. (3 hrs.)

Agricultural Meteorology: Meaning and scope; components of agricultural meteorology; importance of weather and climate for agricultural production; role and responsibilities of agricultural meteorologists. (2 hrs.)

Weather and Climate Relation to Plants and Crops: Principles of crop production; evaluation of crop responses to weather elements; impact of variability of climate on crop production; insects and plant diseases; climate classification; agro-climatic zones and agro-ecological regions of Nepal. (6 hrs.)

Crop Weather Calendars: Weather forecasts for agriculture at short, medium and long range levels; agromet advisories, forecasts and warning for agriculture and forestry; benefits of weather services to agriculture. (4 hrs.)

Weather Hazards in Agriculture: Droughts, types of droughts and their causes; prediction of drought; floods, hail, dew, frost and protection against them; windbreaks and shelterbelts; hail suppression, dissipation of fog, modification of frost intensity and severe storms; mulches and anti-transpirants; meteorological conditions in artificial and controlled climates; green, plastic, glass and animal houses. (6 hrs.)

Crop Weather Models: Empirical and statistical crop weather models; regression models; growth and yield prediction models; crop simulation models, e. g. CERES, WOFOST, SPAW, RESCAP, WTGROW; forecasting of pests and diseases. (6 hrs.)

References

Guide to Agricultural Meteorological Practices by WMO No.134, 1981

Venkskevitch, G. Z., Agro meteorology, Israel Program for Scientific Transition, IPST press, Jerusalem, 300 pp., 1961.

WMO (2001), Lecture Notes for Training Agricultural Meteorological Personnel, WMO no 551, World Meteorological Organization, Geneva.

Course Title: Climate Change Mitigation, Adaptation and Resilience **Credit Hrs: 2**

Course No: Hymet 613 **Lecture Hrs: 30**

Nature of the Course: Theory (Elective) **Full Marks: 50**

Semester: III **Pass Marks:25**

Course Contents:

Climate Change Mitigation, Adaptation: The functioning of the climate system and the causes of climate change, key physical processes of the climate system, Consequences of Climate change on human living circumstances and access to the resources including land, water, energy and food, Climate Mitigation measures, Climate Adaptation strategies in different sectors. Community-based adaptation and national adaptation planning (6 hrs.)

Climate Resilience: Introduction of climate resilience, Climate Resilience Framework and technology, national Resilience Solutions, provincial Solutions and local level Solutions, socioeconomic implications and challenges for climate resilience. (3 hrs.)

Climate Action and Solutions: Principle of the climate solution, Building Solutions: Creating Resilience to Climate Change, reducing emissions, radiative forcing, Low Carbon technologies; renewable energy, energy efficiency, carbon sequestration/carbon capture and storage technologies, methods for climate action. (6hrs.)

Climate Finance: Overview of Climate finance, Types and sources of climate finance, Climate impact on social and economic systems**,** research method for climate change finance, role of local, national and international organizations in climate financing (3hrs.)

Climate Policies (International/ National): International policy, particularly the UN Framework Convention on Climate Change, The Paris Agreement National Climate Policy of Nepal, Indigenous knowledge of climate change, Historical background of COPs, achievements and implications. (4hrs.)

Climate Negotiation: Introduction to Climate negotiation, Climate negotiation needs and process, Nepal's engagement in the climate change negotiations: (3hrs.)

Climate and Sustainable Development: Climate and Sustainable Development Goals; strengthen resilience and adaptive capacity to climate-related disasters, integrate climate change measures into policies and planning, build knowledge and capacity to meet climate change, implement the

UN framework convention on climate change, promote mechanisms to raise capacity for planning and management. (5hrs.)

References

Hardy, J.T. (2004). Climate change: causes, effects and solutions. John Wiley and Sons Ltd., Chichester.

Harvey, L.D.D. (2010). Global warming: the hard science. Pearson Education Limited, Harlow.

Houghton, J. (2004). Global warming: the complete briefing. Cambridge University Press, Cambridge.

IPCC. (2006). Guidelines for national greenhouse gas inventories. Intergovernmental Panel on Climate Change, Geneva.

IPCC. (2013). Climate change 2013: the physical science basis. In T.F Stocker, D. Qin, G.K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (Eds.) *Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1535.

Jones, R.G., Noguer, M., Hassell, D.C., Hudson, D., Wilson, S.S., Jenkins, G.J., and Mitchell, J.F.B. (2004). Generating high resolution climate change scenarios using PRECIS. Met Office Hadley Centre, Exeter.

MoE, (2010). National Adaptation Program of Action (NAPA) to climate change. Ministry of Environment, GoN, Kathmandu.

MoE. (2011). Status of climate change of Nepal. Ministry of Environment, GoN, Kathmandu.

MoPE. (2016). Intended Nationally Determined Contributions (INDC) communicated to the UNFCCC Secretariat in February 2016. Ministry of Population and Environment, GoN.

Smith, J. and Peake, S. (2009). Climate change from science to sustainability. Oxford University Press, Oxford.

UNFCC. (2011). Clean Development Mechanism methodology booklet (information including EB 6). United Nations Framework Convention on Climate Change, Bonn.

Course Title: Applied Climatology and Climate Modeling Practical **Credit Hrs: 2**

Course No: Hymet 614 **Lecture Hrs: 30**

Nature of the Course: Practical (Elective) **Full Marks: 50**

Semester: III **Pass Marks:25**

Course Contents:

Lab 1-3: Develop the precipitation, and temperature climatology of Nepal utilizing the open-access tools from NOAA. The seasonal, and annual climatology should be developed for both temperature and precipitation using ERA5, JMA55, NCEP, CRU etc. (9 hrs.)

Lab 4 - 5: Consider the CMIP5 multi-model data to evaluate the precipitation and temperature change in historical and future projections (considering both RCP4.5 and RCP8.4) for Nepal taking average utilizing the open access tool from KNMI. (6 hrs.)

Lab 6 - 7: Consider the CMIP6 multi-model data to evaluate the precipitation and temperature change in historical and future projections (considering both SSP245 and SSP585) for Nepal taking average utilizing the open access tool from KNMI. (6 hrs.)

Lab 8 - 9: Evaluate the CMIP5 and CMIP6 future projections considering all four seasons and annual precipitation and temperature change in Nepal. (6 hrs.)

Lab 11: Evaluate the historical observations/reanalysis and climate model performance to produce the precipitation and temperature for Nepal considering monthly data. (3 hrs.)

Lab 12-13: Bias correction of daily climate model data utilizing the observations (precipitation and temperature). (6 hrs.)

Lab 14-15: Site visit of agromet observatories; observe soil climate; observe radiation; observe soil temperature; observe soil moisture; observe evaporation and evapotranspiration; observe lysimeters; open pan evaporimeters; phenological observations and measurements. (6 hrs.)

Lab 16: Agrometeorological instruments and their installation, special instruments used for field research in experimental crop field and procedure for taking observations. (3 hrs.)

Lab 17: Data collection and analysis of Soil climate, radiation, soil temperature, soil moisture, evaporation and evapotranspiration. (3 hrs.)

Lab 18: Agro-ecological zoning and Crop yield data monitoring/ analysis. (3 hrs.)

Lab 19-23 Compare the current COP with previous. 15 hrs.)

Lab 24-30: Develop a Climate Policy framework for Local level, Province level, and National level. (21 hrs.)

References:

Web-based Reanalysis Intercomparison Tool: Monthly Maps. Available at https://psl.noaa.gov/data/atmoswrit/map/

Advancing reanalysis. Available at https://reanalyses.org/atmosphere/tools

Climate Explorer. Available at https://climexp.knmi.nl/start.cgi?someone@somewhere

Courses Distribution: Third Semester
(Elective- **Water Resources Stream**)

SN	Course Code	Course Name	Credits	Marks
1	Hymet.621	Hydrological Analysis	2	50
2	Hymet.622	River Hydrology	2	50
3	Hymet.623	Sedimentology	2	50
4	Hymet.624	Hydrological and Sediment Modeling Practical	2	50
		Total	8	200

Course Title: Hydrological Analysis **Credit Hrs: 2**

Course No: Hymet 621 **Lecture Hrs: 30**

Nature of the Course: Theory (Elective) **Full Marks: 50**

Semester: III **Pass Marks:25**

Course Contents:

Introduction: Physical approach, systems approach, problems and models in hydrology. (2 hrs.)

Infiltration Component of the Rainfall-Runoff Process: 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, 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. **(**6 hrs.)

Watershed Conceptual Models: Rational method, Crawford Model, Tank Model, Unit hydrograph models; structure, behavior and building models. (2 hrs.)

Linear Black-Box Models: Types of catchment response, rational method: methodology, effect of catchment shape, 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. (4 hrs.)

Linear Conceptual Models: General hydrologic system model, linear system in continuous time, response function of linear systems: impulse response function, step response function, pulse response function, Nash model. (4 hrs.)

Channel Flow Routing: 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, dynamic waves. (4 hrs.)

Catchment Routing: 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. (4 hrs.)

Catchment Modeling: Introduction to HEC-HMS, SWAT, GDM hydrological model, performing simulations and application. (4 hrs.)

References

Hydrology and Hydrologic Modelling: Proceedings of 26th International Conference on Hydraulics, Water Resources and Coastal Engineering (HYDRO 2021), by P. V. Timbadiya (Editor), P. L. Patel (Editor), Vijay P. Singh (Editor), Priyank J. Sharma (Editor).

Jain, S.K., and Singh V. P., (2019), Engineering Hydrology an Introduction to Processes, Analysis, and Modeling, McGraw Hill Education.

Maskey S. (2022), Catchment Hydrological Modelling: The Science and Art, Elsevier.

Petersen, M.S. (1986). River Engineering. Prentice Hall.

Sherman, L. K. (2016), Stream Flow from Rainfall by the Unit Graph Method, Engineering News Record, 108:501–505, 1932.

Singh, V. P. (Ed.) 2016, Handbook of Applied Hydrology. 2nd ed. New York: McGraw-Hill.

Course Title: River Hydrology **Credit Hrs: 2**

Course No: Hymet 622 **Lecture Hrs: 30**

Nature of the Course: Theory (Elective) **Full Marks: 50**

Semester: III **Pass Marks: 25**

Course Contents:

Introduction, Functions and Uses of Rivers: Brief historical outline, human interference in river, changes in the riverine environment, natural functions, human use of rivers, hazards due to rivers, effects due to the changes in the catchment area, potential conflicts, rivers, technology and society lessons learning in water management in Nepal. (2 hrs.)

Rivers and their Behaviors: General, river regime theory, classification and 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, cutoff, braided rivers, causes of braiding, characteristics of a braided pattern, effect of dam on river regime. (4 hrs.)

Bed Forms: Formation of Bed Forms, Types of bed forms, field data of bed forms, implication of bed forms, prediction of shape, dimensions of bed forms and their migration; flow regimes flow resistance in mobile- bed channels. (2 hrs.)

Hydraulic and Open Channel Flow: Basic concepts of open channel hydraulics, Types of Flow, Flow profiles- Characteristics and Types, Gradually Varied steady/unsteady Flow, rapidly varied flow, spatially, super critical flow, hydraulics of mobile bed channel, open channel flow, St. Venant's Equations, Flow in Closed Conduits, Surge tanks, Energy dissipators, Fish passage facilities, Trash rack, Gates, Dam outlets works and valves, Culverts; drops, dams, weirs, sluice gates, spillways, intakes, Turbines, Power canal and forebay, Penstocks, pressure conduits and shafts, Draft tubes. (5 hrs.)

River Dynamics, Stream Power and Related Theories: General, fluvial processes, morphological prediction, improved Lane's Balance, concept of stream power; theory of minimum energy dissipation. (2 hrs.)

River Morphology and River Engineering: Plain forms, longitudinal profile, bend, channel characteristics, bifurcation and confluences, bed regulation, discharge control, water level control, and water quality control. River engineering for different purposes. (2 hrs.)

Limnology and River Ecosystem: Lake/pond and its classification, dynamic processes in lake/pond/reservoir, thermal stratification, spatial distribution of Lakes/pond in Nepal, global distribution of Lake/pond and sea, morphology of Lake/pond and sea, micro-meteorological impact of artificial lake/pond/reservoir, parameters of the lake, depth-area- volume relationship, lake/river ecosystem, water quality of river, aquatic plants and animals. (4 hrs.)

Fluvial Geomorphology: 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. (4hrs.)

Flood Hydrology: Introduction, causes and effects of floods, time of concentration, runoff coefficient, Design flood and its frequency, methods of estimation of design flood, flood frequency studies, regional flood frequency analysis, guidelines for selecting design floods, risk, reliability and safety factor, Flood forecasting, warning, mitigation and management, flood routing. (3 hrs.)

Flood Hazard Mapping, Vulnerability and Community Participation: Flood hazard mapping, river engineering structures; check dam, retaining wall/ toe wall, spur, revetment, embankment, dyke, rip-rap, terracing, drop structure, flume / chutes, vulnerability to hydraulic infrastructure, climate change vulnerability assessment of hydraulic infrastructure, indigenous technology. (2 hrs)

References:

Brookes, A. (1988). Channelized Rivers: Perspectives for Environmental Management. Wiley-Interscience.

Chow, V.T. (1959). Open channel Hydraulics. McGraw-Hill, USA.

Leeder, M.R. (1982). Sedimentology: Process and Product. George Allen and Unwin, London.

Simons, D.B. & F. Sentürk (1992), Sediment Transport Technology; Water and Sediment Dynamics. Water Resources Publ, LLC, Highlands Ranch, Colorado.

Thorne, C.R. (1998). Stream Reconnaissance Handbook: Geomorphological Investigation and Analysis of River Channels. John Wiley and Sons, England.

Vries, M. de (1993). Use of Models for River Problems. Studies and reports in hydrology.

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

Course Title: Sedimentology **Credit Hrs: 2**

Course No: Hymet 623 **Lecture Hrs: 30**

Nature of the Course: Theory (Elective) **Full Marks: 50**

Semester: III **Pass Marks: 25**

Course Contents:

Introduction: Process of erosion, factor affecting erosion, types of erosion, sources of erosion, estimation of erosion, surface erosion and soil loss, source of sediment, Factor affecting sediment yield, Sediment properties, sediment's transportation. (2 hrs.)

Measurement and Estimation of Soil Erosion and Sediment Load: Introduction, erosion process, types of erosion, slope failure, measurement, and estimation of erosion, field measurement of erosion, erosion modeling with USLE and RUSLE, Physical properties of water and sediment, sediment grade scale, size distribution curve, representative size for graded sediments, Sediment load, Estimation of Sediment load, network design of sediment measurement, catchment sediment yield estimates; sediment delivery ratio; estimating potential accumulation; flow duration and sediment rating curves. Spatial and temporal variability in sediment yield, Sediment Yield from Watersheds, sediment routing. (4 hrs.)

Dynamics of Sediment Movement: Physical properties of water and sediment, Theory of sedimentation, Stoke's law, sediment grade scale, size distribution curve, representative size for graded sediments. 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. (4 hrs.)

Sediment Transport: Bed load transport; analysis and prediction of transport rates; saltation. Suspended sediment transport; 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, wash load, Total bed material load; Computation of total bed-material load using different methods, Catchment sediment yield estimates; sediment delivery ratio; estimating potential accumulation; flow duration and sediment rating curves, Sampling equipment and methods; laboratory analysis and computation of sediment discharge. (4 hrs.)

Degradation, Aggradation, Sorting and Armouring: 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, physical and biological factors affecting incision and aggradation rates. (2 hrs.)

Reservoir Sediment: 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, 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. (4 hrs.)

Lakes and Sedimentological Environments: Lake types and classification. Controls on lake form. Lake stratification. Sediment sources and sediment accumulation processes, Sources and characteristics of lake sediments. Suspended particulate matter in lakes. Chemical and biochemical sediment deposition. Temperate lake chemical processes. Saline lake chemical processes, Controls on lake sediment transport and accumulation, storms and mass movements. Lake-level fluctuations. Lake sediment pollution. Toxicity of chemical water and lake sediment pollutants, climate change impact on lakes. (4 hrs.)

Mountain Sediment: Characteristics. Definition and classification. Mountain sediment cascade. Sediment yields, budget and transfer processes. Subaerial fans: alluvial and colluvial, physical processes of sedimentation. Debris-flow-dominated fans. stream-flow-dominated fans. Natural and climatically induced slope failures, sources of sediment/debris (landslides, LDOF, GLOF), impact of climate change in sediment transport. (4 hrs.)

Reduction in Soil Erosion and Sediment Yield: Sediment study of water-related infrastructure, sediment management, sediment handling in water resources projects, flushing, sediment evacuation, decommissioning of dams, environmental and regulatory issues. (2 hrs.)

References:

Brookes, A. (1988). Channelized Rivers: Perspectives for Environmental Management. Wiley-Interscience.

Chow, V.T. (1959). Open channel Hydraulics. McGraw-Hill, USA.

Leeder, M.R. (1982). Sedimentology: Process and Product. George Allen and Unwin, London.

Simons, D.B. & F. Sentürk (1992), Sediment Transport Technology; Water and Sediment Dynamics. Water Resources Publ, LLC, Highlands Ranch, Colorado.

Thorne, C.R. (1998). Stream Reconnaissance Handbook: Geomorphological Investigation and Analysis of River Channels. John Wiley and Sons, England.

Vries, M. de (1993). Use of Models for River Problems. Studies and reports in hydrology.

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

Course Title: Hydrological and Sediment Modeling **Credit Hrs: 2**

Course No: Hymet 624 **Lecture Hrs: 90**

Nature of the Course: Practical (Elective) **Full Marks: 50**

Semester: III **Pass Marks: 25**

Course Contents:

Lab 1-4: Hydrological modeling of the river basin from semi-distributed model	(12 hrs.)
Lab 5-8: Hydrological modeling of the river basin from the distributed model	(12 hrs.)
Lab 9-12: Snow and Glacier melt modeling of the river basin	(12 hrs.)
Lab 13-16: Groundwater modeling of the river basin	(12 hrs.)
Lab 17-20: Reservoir optimization modeling	(12 hrs.)
Lab-21-24: Sediment modeling of the river basin	(12 hrs.)
Lab 25: Estimation of soil erosion/loss of the watershed.	(3 hrs.)
Lab 26: Estimation of debris flow velocity using various approaches.	(3 hrs.)
Lab 27: Estimation of sediment yield of reservoir from bathymetric data.	(3 hrs.)
Lab 28: Petrographic analysis of total sediment, and bed material of the river.	(3 hrs.)
Lab 29-30: Review of sediment handling of the water resources projects.	(6 hrs.)

References

Hydrology and Hydrologic Modelling: Proceedings of 26th International Conference on Hydraulics, Water Resources and Coastal Engineering (HYDRO 2021), by P. V. Timbadiya (Editor), P. L. Patel (Editor), Vijay P. Singh (Editor), Priyank J. Sharma (Editor).

Jain, S.K., and Singh V. P., (2019), Engineering Hydrology an Introduction to Processes, Analysis, and Modeling, McGraw Hill Education.

Maskey S. (2022), Catchment Hydrological Modelling: The Science and Art, Elsevier.

Sherman, L. K. (2016), Stream Flow from Rainfall by the Unit Graph Method, Engineering News Record, 108:501–505, 1932.

Simons, D.B. & F. Sentürk (1992), Sediment Transport Technology; Water and Sediment Dynamics. Water Resources Publ, LLC, Highlands Ranch, Colorado.

Singh, V. P. (Ed.) 2016, Handbook of Applied Hydrology. 2nd ed. New York: McGraw-Hill.

Vries, M. de (1993). Use of Models for River Problems. Studies and reports in hydrology.

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

Courses Distribution: Third Semester (Elective- Cryosphere Stream)

SN	Course Code	Course Name	Credits	Marks
1	Hymet.631	Remote Sensing and Cryosphere Modeling	2	50
2	Hymet.632	Advance Glaciology	2	50
3	Hymet.633	Snow and Permafrost	2	50
4	Hymet.634	Snow Modeling and Cryosphere Practical	2	50
		Total	8	200

Course Title: Remote Sensing and Cryosphere Modeling **Credit Hrs: 2**

Course No: Hymet 631 **Lecture Hrs: 30**

Nature of the Course: Theory (Elective) **Full Marks: 50**

Semester: III **Pass Marks:25**

Course Contents:

Introduction to Remote Sensing and the Cryosphere: Fundamentals of remote sensing techniques and their applications in cryospheric studies, importance of monitoring cryospheric changes, history and the key development in remote sensing technology. (2 hrs.)

Electromagnetic Spectrum and Sensors: Overview of the electromagnetic spectrum and its relevance to remote sensing, types of sensors (optical, microwave, thermal) used for cryospheric observations. (2 hrs.)

Remote Sensing Platforms and Products: Satellites, details and types of satellite, past present and future aircraft, drones, and ground-based platforms used for cryospheric remote sensing, remote sensing datasets and products for cryosphere, accessing and utilizing data from satellite missions (4 hrs.)

Snow and Ice Albedo Measurement: Measurement and analysis of albedo (reflectivity) of snow and ice surfaces, role of albedo in energy balance and melt processes (2 hrs.)

Glacier Monitoring: Techniques for tracking glacier extent, velocity, and volume changes, uses of optical and SAR data for glacier dynamics studies, introduction to xDEM and geodetic mass balance using xDEM (5 hrs.)

Permafrost Studies: Detection and mapping of permafrost regions using remote sensing data, monitoring permafrost temperature and thawing processes. (2 hrs.)

Snow Cover Mapping and Monitoring: mapping and tracking of snow cover and depth using optical and SAR data. (2 hrs.)

Future Challenges and Innovations: Emerging technologies in cryospheric remote sensing (e.g., LiDAR, synthetic aperture radar, UAV, field-based technologies), challenges in data interpretation, validation, and uncertainty assessment. (3 hrs.)

Modeling: Concept of modeling, Coupled Cryosphere-Climate Models, types of modeling in cryosphere, Glacio-hydrological modeling, Snowmelt-runoff modeling (point snowmelt model, distributed snowmelt model, different types of model), Glacier-mass balance modeling,

(Temperature index model, Energy balance model on clean and debris covered glacier), introduction to different energy balance modeling, avalanche modeling. (5 hrs.)

Uncertainty and Sensitivity Analysis: Sources of Uncertainty in Cryosphere Models, Sensitivity Analysis and Parameterization. (1 hr.)

Artificial Intelligence: Concepts, application of AI in cryospheric studies (2 hrs.)

References:

Dewalle, D. R and Rango A., Principles of snow hydrology, Cambridge University Press

Nakawo, M. and Hayakaya, N. Snow and Ice Science in Hydrology, Nagoya University.

Oke, T. R. Boundary layer climate, Routledge, London and New York, 1996.

Peterson,W. S. B. ‘’The Physics of Glaciers, II Edition, 19..,Elsevier Science Ltd.

Course Title: Advance Glaciology **Credit hrs: 2**

Course No: Hymet 632 **Lecture hrs: 30**

Nature of the Course: Theory (Elective) **Full Marks: 50**

Semester: III **Pass Marks:25**

Course Contents:

Glacier Mass Balance: Components of mass balance of a glacier, graphical representation of glacier mass balance, importance and application of glacier mass balance study, estimation of glacier mass balance, different methods of measurement of glacier mass balance, estimation methods of glacier mass balance (surface, subsurface and basal). (3 hrs)

Structure and Deformation of Ice: Structure of the ice crystal, Deformation of a single crystal Deformation of polycrystalline ice, Flow relations, Field measurements of flow parameters Values of flow parameter (2 hrs.)

Flow Laws of Glacier Ice: Flow law of polycrystalline ice, general flow law of ice, ice flux, glacier flow laws in parallel and non-parallel intermediate surfaces, velocities in laminar flow and non-laminar flow, basal sliding in glaciers: Weertman's theory, velocities in extending and compressive flow in glacier ice, application and modification of theoretical laws in glacier flow, surging of glacier. (3 hrs.)

Glacier Surge: Glacier surges and characteristics of surging glaciers; surge mechanisms, geographic locations of surging glaciers. (1 hr.)

Field Based Glacier Monitoring: Principle and importance of field-based glacier monitoring, instruments, basic skills needed to calculate point energy balance on glaciers, point mass balance, mass balance gradient, DGPS measurements, challenges, altitude related illness, (2 hrs.)

Heat balance components and their estimation: Heat balance equations, heat balance on the surface of snow, ice or glaciers, net radiation and it's estimation, ground heat flux, precipitation heat flux, turbulent fluxes, estimation o of energy balance, modification in energy or mass balance equations for stable, unstable and neutral atmospheric conditions, heat budget parameters and snow environmental. (3 hrs.)

Heat transformation and temperature in glacier and ice sheet: Explanation of equation for temperature and its estimation, temperature profile and distribution of temperature in a glacier

area, general equation of heat transfer in ice layer, temperature of a temperate glacier, Fourier heat conduction theory. (3 hrs.)

Global warming and its impacts: Snowmelt process, high rate of ice melt, circulation and environmental impacts, Impact of global warming on snow and glaciers, black carbon deposition on ice and its impacts. (3 hrs.)

Hydrology of Glacier: glacier melt water system, glacial hydraulic systems (e.g., Supra, Englacial, sub-glacial), changes in glacier hydrological regimes due to climate change, sea-level rise and glacier contributions. (3 hrs.)

Glacial Lakes and Glacial Lake Outburst Flood: Glacier lake and its outburst flood (GLOF) in HKH, introduction: glacier, moraine, debris, glacier lakes: definition, types, evolution records and data base of GLOF in Nepal and HKH, potentially dangerous glacier lakes, estimation of floods (GLOF) and possible damages, mitigation system and process for GLOF in Nepal. (3 hrs.)

Ice core and glacier dating: Introduction and importance, Isotopes in ice core (oxygen, carbon, magnesium), impurities in ice cores, climatic interpretation and dating, glacier collapse, recent events and link with climate change, impact. (2 hrs.)

Avalanche formation process and release; Types of avalanches, factors contributing to avalanche release, including slope angle, snowpack stability, and triggers (natural and human-induced). (1 hr)

Avalanche Forecasting and Warning Systems: Avalanche forecasting techniques, monitoring and data collection (e.g., snowpack tests, weather data), Avalanche danger scale and terminology, Avalanche risk assessment, adaptation and mitigation (1 hr)

References:

Dewalle, D. R and Rango A., Principles of snow hydrology, Cambridge University Press

Paterson, WSB, The Physics of Glaciers, 2nd and 3rd Edition, Elsevier Science Ltd. Kingster, England, 1994.

Course Title: Snow and Permafrost **Credit Hrs: 2**

Course No: Hymet 633 **Lecture Hrs: 30**

Nature of the Course: Theory (Elective) **Full Marks: 50**

Semester: III **Pass Marks:25**

Course Contents:

Snow: Definition, formation and distribution of snow, shapes of snowflakes, snow avalanche snow observation and measurement technique, water equivalent, metamorphism of deposited snow; classification of deposited snow, metamorphism process in deposited snow. (4 hrs.)

Transformation of Snow to Ice: Snow, firn and ice, variation of density with depth, depth hoar transformation of snow into ice in dry & wet conditions, age of air in bubbles and its disappearance, rate of crystal growth. (2 hrs.)

Snow Pack Condition: Snow metamorphism, heat conduction**,** liquid water content**,** transformation of snow to ice in dry and wet snow zone, deformation process of polycrystalline ice and basic equation, snowmelt process. (3 hrs.)

Seasonal Snow Cover: Introduction of seasonal snow cover, metamorphism of dry snow: equi-temperature metamorphism, temperature gradient metamorphism, constructive and destructive metamorphism, melt metamorphism, effect of temperature and wind, properties of dry and wet snow: thermal and mechanical properties, turbulent diffusion, saltation, sublimation and blowing snow. (3 hrs.)

Snow Measurement Techniques: In-situ and remote sensing based snow monitoring practices and purposes, instruments, challenges and remote sensing of snow monitoring, current status of snow monitoring in Nepal, HKH and in the world. (3 hrs.)

Snow Pack Energy Exchange: Heat balance principle, heat balance on the surface of land, snow, ice and glaciers, lake water; net radiation and it's estimation, ground heat flux, estimation of precipitation heat flux, turbulent heat fluxes, estimation methods and their contribution to energy balance, modification in energy, energy budget examples and application, topographic and forest effects on energy exchange. (4 hrs.)

Snowmelt-runoff: Snow pack water balance, storage and time lag, melt water flow path, snow melt hydrograph, contribution of snowmelt to stream flow**.** (3 hrs.)

Climate Change and Snow Dynamics: Potential impact of climate change on snow and glacier dynamics. (2 hrs.)

Rock Glaciers and Permafrost: Definition, types, distribution, rock glacier as an indicator of the existence of permafrost. (2 hrs.)

Permafrost Changes and Impacts: Variability in time and space, projection of changes in permafrost, Sudden-onset and slow-inset events due to thawing permafrost, impacts of thawing permafrost on livelihoods (infrastructure and people), landscape and ecosystem, hydrological regime. (2 hrs.)

Climate Change and Permafrost: Impacts of climate change on permafrost, permafrost in climate models, Permafrost in hydrological models, Global permafrost carbon feedback. (2 hrs.)

Permafrost Related Hazards: Slope instability, debris flow**,** adaptation and mitigation challenges, permafrost in climate policies, engineering challenges related to permafrost. (2 hrs.)

Permafrost Hydrology (1 hr.)

Research Gaps Snow and Permafrost Research in High-mountain Asia (1 hr.)

Cryosphere, Ecosystem, and Society (2hrs.)

References:

Dewalle, D. R and Rango A., Principles of snow hydrology, Cambridge University Press

Nakawo, M. and Hayakaya, N. Snow and Ice Science in Hydrology, Nagoya University.

Oke, T. R. Boundary layer climate, Routledge, London and New York, 1996.

Peterson,W. S. B. ‘’The Physics of Glaciers, II Edition, 19..,Elsevier Science Ltd.

Course Title: Remote Sensing and Modelling of Cryosphere Practical **Credit Hrs: 2**

Course No: Hymet 634 **Lecture Hrs: 30**

Nature of the Course: Practical (Elective) **Full Marks: 50**

Semester: III **Pass Marks:25**

Lab 1-2: Field glacier mass balance: point energy balance on glaciers, point mass balance, mass balance gradient, DGPS measurement and data processing (6 hrs.)

Lab 3-6: Energy balance model (12hrs.)

Lab 7-8: Glacio-hydrological model (6 hrs.)

Lab 9-11: Image classification with band ratios in QGIS (clean ice and snow, vegetation, clouds, etc.) (SCP plugin in QGIS) (9 hrs.)

Lab 12-13: Glacier dynamics by Feature tracking: IMCORR plugin (6 hrs.)

Lab 14-15: Terrain analysis: DEM pre-processing: clipping, re-projecting, merging, etc. (6 hrs.)

Lab 16-18: DEM co-registration with QGIS and XDEM (9 hrs.)

Lab 19-21: Use of DEM to calculate glacier mass and volume change. (9 hrs.)

Lab 22-23: Automated image segmentation: Geo-SAM tool (QGIS plug-in). (6 hrs.)

Lab 24-26: Mapping rock glacier using open-source tools. (9 hrs.)

Lab 27-30: Snow cover change using MODIS data (12hrs.)

References

Dewalle, D. R and Rango A., Principles of snow hydrology, Cambridge University Press

Nakawo, M. and Hayakaya, N. Snow and Ice Science in Hydrology, Nagoya University.

Oke, T. R. Boundary layer climate, Routledge, London and New York, 1996.

Paterson, WSB, The Physics of Glaciers, 2nd and 3rd Edition, Elsevier Science Ltd. Kingster, England, 1994

Courses Distribution: Fourth Semester

SN	Course Code	Course Name	Credits	Marks
1	Hymet.651	Project Management	2	50
2	Hymet 652	Thesis	8	200
		Total	10	250

Course Title: Project Management **Credit Hrs: 2**

Course No: Hymet 651 **Lecture Hrs: 30**

Nature of the Course: Theory (Compulsory) **Full Marks: 50**

Semester: IV **Pass Marks:25**

Course Contents:

Introduction: Definition of project and project management, project objectives, project management standards, classification of projects, advantages of project management, fundamental project management approaches, phases of project management life cycle, project development methodologies, role and responsibilities of key project members. (2hrs.)

Project Management Body: Understanding of project environment, central management skill, effective and ineffective project managers, essential interpersonal and managerial skills, energized and initiator, communication, influencing, leadership, planner, motivator, negotiation, problem solver, perspective nature, result oriented, global illiteracies, problem-solving using problem trees, portfolio, project management office, drivers of project success, inhibitors of project success, monitor and control project work, integrated change control, close project, project scope management, create work break down structure, scope verification, scope control. (4 hrs.)

Project Management Process and Organizational Structure: Develop project charters, develop preliminary project scope statement, develop project management plan, direct and manage project execution, project management processes, overlaps of process groups in a phase, mapping of project management process groups to area of knowledge, system view of project management, functional organization, matrix organization, organizational structure influences on projects. (4 hrs.)

Project Cost Management: Cost and project, steps in project cost management (project resource planning, cost estimation, cost budgeting, cost control), cost estimating, types of cost estimates, estimating process and accuracy, enterprise environmental factors, organizational process assets, cost estimating tools, cost budgeting, cost control, cost aggregation, deriving budget from activity cost, cost control process, cost control methods, cost management, earned value management (EVM), variance analysis. (4 hrs.)

Project Communication and Quality Management: Importance of communication management, communication planning process, communication requirement analysis,

stakeholder's role in ensuring project success, communication mechanism in project success, method and tools of time management, organizing and conducting effective meeting, information distribution process, performance reporting process, project presentations, integrated reporting system, quality theories, quality planning, project quality requirements, cost of quality, quality management plan, quality assurance, quality audit, approach to a quality audit, quality control process, control chart, pareto charts, project closure. (4 hrs.)

Project Time Management Quality Management: Definition of time management, importance of time management, time management strategies, decomposition of activities, activity attributes, activity sequencing, precedence relationship, network diagram, precedence diagram method, arrow diagramming method, activity resources estimating, determining resource requirements, schedule development and control, principles of scheduling, milestones, forward pass, backward pass, critical path method, critical chain technique, Gantt chart, quality planning, quality assurance, quality control, schedule control. (4 hrs.)

Managing Stakeholders, Monitoring & Evaluation of Development Project: Introduction to participatory approach, stakeholder mapping or venn diagram, beneficiaries/target groups(communities, gender & social equity, social inclusion of DAG others), partners (donors, NGOS, CBOS), transparencies/accountability, periodic review of the project, initial, annual, midterm review, project activities modification based up on review result; resource audit, public audit, evaluation of the project, documentation and dissemination of project out comes and lesson learned, project proposal development and report writing, beyond project. (4 hrs.)

Project Risk Management: Understanding project risk, classification of project risk, external and internal risk, political unexpected events, terrorism, life cycle of project risk, risk management planning process, risk management plan, risk identification techniques, risk manager, risk profile, risk analysis (qualitative and quantitative risk analysis), modeling techniques, risk response planning, resolution of risk, strategies for negative risks or threats, strategies for positive risks or opportunities, risk monitoring (tracking and controlling), risk response, recording risk, closure of risk. (4 hrs.)

Project Procurement Management and Custom Processes: Procurement management process flow, plan purchases and acquisition process, enterprise environmental factor, organizational process assets, contract types, plan contracting process, standard forms, evaluation criteria, request seller response process, select seller process, contract administration process, contract closure

process, moving forward with customized management processes, certified associate in project management, project management maturity, promoting project excellency through awards and assessment, certification process flow, code of ethics, future trends, procurement acts of Nepal, role and responsibility of public procurement monitoring office, donor agencies interest/strategies /involvement in rural development of Nepal, GON development strategies/planning; Five-year plan of GON. (2 hrs.)

References

Larson, E.W. and Gray C.F. (2011), Project Management: The Management Process, McGraw-Hill/Irwin, New York.

Young, T.L. (2007) The Handbook of Project Management. 2nd Edition, Kogan Page Limited, London.

Meredith, J. and Mantel, S. J. (1989). Project Management: A Managerial Approach. J Wiley, New York.

Heagney J. (2011). Fundamental of Project Management, Fourth Edition American Management.

Richardson G.L and Jackson B.M. (2019). Project Management Theory and Practice, Third Edition, CRC Press. Taylor & Francis Group, New York.

Course Title: Thesis **Credit Hrs: 8**

Course No: Hymet 652 **Full Marks: 200**

Nature of the Course: Compulsory **Pass Marks:100**

Semester: IV

Thesis work: All students must complete thesis work related to his/her area of specialization. They will submit a thesis to the department for which eight credits (200 marks) will be allocated.

Courses Distribution: Non-credit Course

SN	Course Code	Course Name	Credits	Marks
1	Hymet.661	Statistical Application for Hydro-meteorological Data Analysis		
2	Hymet. 662	GIS and Remote Sensing Applications on Hydro-meteorology		
3	Hymet. 663	Natural Resources Management		
4	Hymet. 664	Socio-economic Aspect of Climate and Water Resources		
5	Hymet. 665	Springshed Management		
6	Hymet. 666	Application of Field and Remote Sensing Technique for Snow and Glacier Study		
7	Hymet. 667	Monsoon Meteorology		
8	Hymet. 668	Environmental Impact Assessment (EIA)		
9	Hymet. 669	Programming in Hydro-meteorology		
10	Hymet. 670	Conflicts in Water Resources		
11	Hymet. 671	Economics, Legal and Policy Dimensions of Climate Change		
12	Hymet. 672	Renewable Energy Resources		

Course Title: Statistical Application for Hydro-Meteorological Data Analysis **Credit Hrs:**

Course No.: Hymet 661 **Lecture Hrs.: 45**

Nature of the Course: Theory (Non-credit) **Full Marks:**

Semester: **Pass Marks:**

Course Contents:

Statistical Concepts in Hydrology and Meteorology: Nature, classification and presentation of data; Frequency distribution; Measures of central tendency: mean, median, mode, quartiles, percentiles, skewness and kurtosis; Measures of dispersion: range, quartile deviation, mean deviation, standard deviation and coefficient of variation. (5 hrs.)

Statistical Methods and Probability Distributions: Overview of statistical methods; Descriptive statistics in meteorology; Probability distributions in meteorology; Hypothesis testing and confidence intervals; Parametric and non-parametric tests in meteorology; Regressions (simple linear and multiple) and correlation analysis. (10 hrs.)

Time Series Analysis and Extreme Value Analysis in Meteorology: Autoregressive integrated moving average (ARIMA) models; Seasonal decomposition of time series (STL); Forecasting methods in meteorology; Frequency analysis of extreme weather events; Gumbel and Weibull distributions; Return period and risk assessment. (5 hrs.)

Spatial Statistics, Uncertainty and Error Analysis in Meteorology: Spatial autocorrelation, kriging and spatial interpolation; Geostatistical analysis in meteorological data; Measurement uncertainties in meteorological data; Propagation of errors in data analysis; Monte Carlo simulations in hydrological and meteorological studies. (5 hrs.)

Stochastic Models for Precipitation and Streamflow: Rainfall-runoff modeling; Point processes; Spatial and temporal variability; Stochastic simulation of precipitation; Stochastic hydrological models; Autoregressive and moving average models for streamflow. (5 hrs.)

Climate Change and Statistical Analysis: Statistical methods for analyzing climate data; Detection and attribution of climate change; Uncertainties in climate model projections; Use of statistics in meteorological research: case studies; Future trends in statistical applications in hydro-meteorology. (5 hrs.)

Multivariate Analysis: Nature of multivariate data; Purpose of multivariate analysis; Gradient analysis; Constrained and unconstrained ordinations: PCA, NMDS, CA, CCA, and RDA; cluster analysis. (10 hrs.)

References

Crawley M.J. (2007). The R Book. John Wiley and Sons Ltd., England, UK.

Crawley M.J. (2012). Statistical computing: an introduction to data analysis using R.

Gupta S.C. (1998). Fundamentals of statistics. Himalayan Publishing House, Mumbai.

Johnson R.A. and Wichern D.W. (2015). Applied Multivariate Statistical Analysis, 6th Edition, Pearson Modern Classic.

Course Title: GIS and Remote Sensing Applications in Hydro-meteorology **Credit Hrs:**

Course No: Hymet 662 **Lecture Hrs: 30**

Nature of the Course: Theory/Lab (Non-credit) **Full Marks:**

Semester: **Pass Marks:**

Course Contents:

Introduction to Remote Sensing and GIS: Basic concepts and definitions, overview of the remote sensing process, development in aerial and space photography, introduction to gis and its applications, remote sensing platforms and sensors. (2 hrs.)

Aerial Photography Satellite remote sensing, photographic flight mission and layout, type of aerial photography, use of conventional aerial photography, Stereoscopy and vertical exaggeration, unmanned aerial vehicles (UAVs), LiDAR and RADAR systems, remote sensing data acquisition and analysis. (2 hrs.)

Image Acquisition Techniques: Image pre-processing and enhancement, Image classification and interpretation, change detection analysis, IS data models and data sources, geometric characteristics of aerial photographs introduction, terminology, mosaic construction and use, stereoscopic parallax, basic geometrical relations of scale, parallax and heights using vertical photographs. (2 hrs.)

Vector data Model: Raster data model, data acquisition techniques (field surveys, GPS), Data sources (satellite imagery, topographic maps, digital elevation models). (2 hrs.)

Photo/image interpretation Principles. Elements of photo/image interpretations hydrological and glaciological applications. (2 hrs.)

Spatial Data Analysis: Spatial data manipulation and processing, spatial interpolation, overlay and proximity analysis, network analysis. (2 hrs.)

Space Missions and Spectrozonal Photography Advances in photographic techniques, types of camera, films and filters, use of spectrozonal photography, important space photographic missions. (2 hrs.)

Concepts and Foundations of Satellite Remote Sensing: Introduction. energy source and radiation principles. energy interactions in the atmosphere. energy interactions with earth surface features. data acquisition and interpretation. (2 hrs.)

GPS and Data Acquisition: Introduction to GPS, GPS data acquisition, errors in GPS data, applications. (2 hrs.)

Spatial Analysis Spatial interpolation methods; raster and vector analysis; map overlay; map calculations; statistics; integrated spatial analysis 1 surface dem, slope, aspect, other raster functions. (2 hrs.)

Making Maps: Map functions in CIS: map design; map elements; choosing a map type; Exporting map in different formats printing a map. (2 hrs.)

GIS Data Management and Database Design: Spatial database concepts, database management systems (DBMS), database design and modelling, data integration and interoperability. (2 hrs.)

Remote Sensing and GIS Applications: Land cover and land use mapping, environmental monitoring, Urban planning and management, Natural resource management, Disaster management and response. (2 hrs.)

Advanced Topics in Remote Sensing and GIS: Hyperspectral remote sensing, LiDAR data processing and analysis, web-based GIS and mobile mapping Geospatial data visualization, remote sensing and GIS integration. (2 hrs.)

Remote Sensing and GIS Project: Undertaking a practical project applying remote sensing and GIS techniques, data collection, analysis, and interpretation, report writing and presentation of results. (2 hrs.)

References

C. P. Lo and Albert K.W. Yeung 2003. *Concepts and techniques of Geographic Information System. Prentice*-Hall India

George Joseph 2005. *Fundamentals of Remote Sensing* 2nd edition. Universities Press (India) Private Limited

Ian Heywood, Sarah Cornelius and Steve Carver 2005. An Introduction to Geographical Information System, Pearson Education

J. R. Jenson 2003. Remote Sensing of the Environment- An Earth resources Perspective. Pearson Education

P. A. Burrough and Rachael A. McDonnell 2003. *Principles of Geographic Information Systems-Spatial Information systems and Geostatistics*. Oxford University Press

R. M. Lillesand and R. W. Kiefer 2002. Remote Sensing and Image Interpretation 4th Ed WSE Wiley.

Course Title: Natural Resources Management **Credit Hrs:**

Course No: Hymet 663 **Lecture Hrs: 30**

Nature of the Course: Theory (Noncredit) **Full Marks:**

Semester: **Pass Marks:**

Course Contents:

Introduction: Introduction to Natural Resources and Management, importance of natural resources, Scopes of natural resource management, renewal and nonrenewal resources, Trends and drivers of resource use (demography, ecological settings, economic growth, patterns of developments, etc.). Causes and consequences of resource depletion, Principles, Issues and approaches (community-based, adaptive and integrated), Concept and evolution of sustainable development, Importance of legal, policy and governance in natural resource management, Introduction of water resources. (4 hrs.)

Land Resources: Concept of land resource and land use, land use types, land use classification, Causes, types and effects of land degradation, Land use and land reform policy, land use planning, land resource management practice (mechanical, biological methods, fertility management). (4 hrs.)

Mineral Resources: Mineral resources, types (metallic and non metallic minerals) and distribution of mineral resources, importance of mineral resources, Rapid depletion, wastage, environmental pollution, Major mineral resources and their status, distribution and extraction in Nepal, Policy, strategy and practice (reuse, recycle, sustainable extraction, etc). (4 hrs.)

Mountain Resources: Importance of mountain as natural resources, degradation and its management. Mountain and tourism. (2 hrs.)

Biodiversity Resource: Biological resource and their types, Ecological, socioeconomic, evolutionary, climatic services, concept, components of biodiversity. State and general threats of biodiversity of Nepal, basic concept and their relevance, concept, policies, strategy and practices (ex-situ and in-situ conservation). (3 hrs.)

Forest Resources: Introduction and importance (economic, ecosystem service, carbon storage/trade, climatic service), forest types and characteristics of Nepal, timber, fuel wood, fodder, NTFP, etc., causes and consequences of forest degradation, Forest management-

management policy, strategy and programs of Nepal, policy, programs and implementation of community forest. (4 hrs.)

Energy Resources: Energy and development, energy types (Renewable and Nonrenewable energy sources), National & International scenario of energy generation and consumption pattern (Role and contribution of biomass resources in national & international energy, e.g. economy and environment) , Concept of renewable and non-renewable energy and the importance of bio-energy in renewable energy (RE), Traditional bio-energy sources, Potential modern bio-energy and alternative energy (AE) sources, Definition, types and potentials of renewable (solar, wind power, hydropower, biomass, geothermal, tidal, etc.) and nonrenewable (coal, oil and natural gas) energy resources, Causes and ecological and economic effects of rapid consumption of fossil fuels, concept of alternative energy, Importance, scope and limitation of non-biomass based alternative energy (solar, hydro, wind, geo-thermal, hydrogen, tidal, nuclear etc.), Role of bio-energy in AE (bio-briquettes, charcoal, wood-fuel, liquid bio-fuel, bio-ethanol, bio-hydro carbon oil, bio-diesel, bio-gas, wood-gas, dendro-thermal power and bio-mass power plant), Status of energy availability and use in Nepal, Energy policy of Nepal. (5 hrs.)

Conflict Management in NRM: Introduction, understanding conflict in NRM, concept and theory of conflict, type of conflict, value of conflict, characteristics and dynamics of conflict, conflict analysis, conflict management, basic principle of managing conflict, conflict resolution, option of conflict management strategies, case studies related to conflicts in natural resources such as water, land and forests. (4 hrs.)

References

DFRS, 2015. State of Nepal's Forests. Forest Resource Assessment (FRA) Nepal, Department of Forest Research and Survey (DFRS). Kathmandu, Nepal.

WECS. (2011). Water resources of Nepal in the context of climate change. Water and Energy Commission Secretariat, GoN, Kathmandu.

ADB (2017), Nepal Energy Sector Assessment, Strategy and Road Map, Asian Development Bank.

Malla, A., and Djamamkauam, P. (2023). Renewable energy in Nepal: Key findings and policy recommendations (Working Paper). ICIMOD.

USAID, (2006), Conflict over Natural Resources at the Community Level in Nepal Including its Relationship to Armed Conflict.

Course Title: Socio-economic Aspect of Climate and Water Resources **Credit Hrs:**

Course No: Hymet 664 **Lecture Hrs: 30**

Nature of the Course: Theory (Noncredit) **Full Marks:**

Semester: **Pass Marks:**

Course Contents:

Introduction to Social Hydrology & Meteorology: Meaning and concept of social hydrology & meteorology; scope of social hydrology & meteorology; relationship of socio-cultural hydrology with other sciences; water as a singular object with multiple ontologies; water: more than a resource – spiritual and religious water practices. (4hrs.)

History of Water Usages: Historical understandings of water from traditional usage to modern usage; paradigmatic changes in water studies and the hydro-social cycle. (3hrs.)

Water Scarcity and Water Security: Concept and meaning of water scarcity and water security; model of water scarcity; water security as a new guideline for policy and research. (3hrs.)

Water Infrastructures: Dam constructions; displacement; resettlement and rehabilitation; upstream-downstream and transboundary conflicts, indigenous people in water resources. (3hrs.)

Debate on Right to Water and Water Rights: Definitions of access to water; access to water as a human right; right to water vs. water rights. (3hrs.)

Commodification and Privatization of Water: Emergence of private sector participation in water supply; resistance to water privatization; different forms of water privatization and commodification. (4hrs.)

Water Governance: Water governance; controlling, managing, and governing water at local (wugs/figs), regional, and national levels; transboundary water governance; global water governance: future water studies in the context of global environmental change. (4hrs.)

Weather Forecasting Systems: (4hrs.)

Knowledge and practices of local/traditional and indigenous weather forecasting; methods of weather forecasting and importance of weather forecasting; linkage between scientific and traditional weather forecasting

From Single Discipline to Interdisciplinary Approach (2 hrs.)

References

Gleick P. H. (2000). The changing water paradigm: a look at twenty-first-century water resources development. Water International. 25:125-138.

Khagram, Sanjeev. 2004. *Dams and development: Transnational struggles for water and power*. Cornell University Press.

Linton, J. (2010). What is Water? The History of a Modern Abstraction. University of British Columbia Press, Vancouver.

Wutich, Amber, Melissa Beresford, Teresa Montoya, Lucero Radonic, and Cassandra Workman, 2022. Water Scarcity and Insecurity. Oxford University of Press.

Course Title: Springshed Management **Credit Hrs:**

Course No: Hymet 665 **Lecture Hrs: 30**

Nature of the Course: Theory (Noncredit) **Full Marks:**

Semester: **Pass Marks:**

Course Contents:

Introduction: Definition and importance of springs, types of springs, an overview of water resources management, socio-economic, cultural and ecological significance of springs and springsheds, causes for drying springs, impact of drying springs on various sectors; difference between watershed management and springshed management. (2 hrs.)

Hydrogeology of Springs: Groundwater dynamics, rock type and properties of rock typology of springs, hydrological processes in springsheds, hydrogeology of springs, mountain aquifer, technical, socio-economic data requirement for springshed management, data collection and analysis techniques, hydro-geological mapping, hydrogeological conceptual layout of the springshed. demarcation and analysis of the recharge area. (4 hrs.)

Water Quality and Quantity Assessment: Water quality parameters and monitoring, techniques for assessing spring water quantity, impact of land use practices on water quality and quantity, isotopic study on springshed management. (4 hrs.)

GIS and Remote Sensing Applications: Importance of digital technologies such as Geographic Information Systems (GIS), remote sensing, mobile apps and others in springshed management, use of digital technologies in mapping, monitoring, and revival of springs. (4 hrs.)

Physical and Biological Assessments in Springsheds and Measures for Spring Revival: Flora and fauna of springsheds, ecosystem services provided by springsheds, physical, biological, and management measures applied in springsheds for the revival of springs, recharge interventions, incentive-based mechanism, and its importance in springshed management. (4 hrs.)

Land Management, Climate Change and Springshed Management: Soil and water conservation practices, watershed planning and management, sustainable agricultural practices, sustainable, management of natural resources, impacts of climate change on springsheds, adaptation and mitigation strategies, and resilience building in the face of climate change. (4 hrs.)

Community Engagement and Social Aspects: Community-based natural resource management, community awareness and mobilization activities, social dynamics in springshed communities,

participatory approaches to springshed management, gender and social inclusive perspectives on management of springshed management, tools for participatory social science research, good governance on springshed management, *Hitis, Rajkulo Tuthi* and *Pokhari*, traditional knowledge of groundwater management in Kathmandu valley, indigenous knowledge of springshed management, six-step protocol for spring revival in the Hindu Kush Himalaya. (4 hrs.)

Policy and Legal Frameworks: Sub-national (local, provincial), national and international policies related to water resources management, national and sub national policies and strategies for springshed management, legal, economic, and political aspects of springshed management. (2 hrs.)

Measuring and Communicating Impact: Hydrological, gender, socio-economic and ecological impacts, cost-benefit analysis of springshed management. Case studies. Communication methods – social media, opeds, peer review articles, videos, others. (2 hrs.)

References:

Department of Soil Conservation and Watershed Management (BCRWME-2014)

Rathod, R.; Kumar, M.; Mukherji, A.; Sikka, A.; Satapathy, K. K.; Mishra, A.; Goel, S.; Khan, M. (2021), Resource Book on Springshed Management in the Indian Himalayan Region: guidelines for policy makers and development practitioners. New Delhi

Shrestha, R.B., Desai, J., Mukherji, A., Dhakal, M., Kulkarni, H., Mahamuni, K., Bhuchar, S. & Bajracharya, S. (2018), Protocol for reviving springs in the Hindu Kush Himalayas: A practitioner's manual. ICIMOD Manual 2018/4. Kathmandu: ICIMOD.

Spring Water Assessment & Management, Ministry of Forests and Soil Conservation

Course Title: Application of Field and Remote Sensing Technique for Snow and Glacier Study

Credit Hrs:

Course No: Hymet 666 **Lecture Hrs: 45**

Nature of the Course: Theory/Lab (Noncredit) **Full Marks:**

Semester: **Pass Marks:**

Course Contents:

Principles of Cryosphere: components; types; glaciers as climatic indicators; glacier mass balance (field and geodetic) and dynamics, etc. (2 hrs.)

Mountain Hydrology: Principles of glacio-hydrology, overview of field measurements, linkage between climate, glaciers, and river flows (2 hrs.)

Recent Mass Balance Evolution of HMA Glaciers, glacier mass balance of HMA glaciers at different scales, from glacier to regional scale, and processes controlling their recent evolution. (2 hrs.)

Glacier and Snow Monitoring: field and remote-sensing based tools and techniques, Glacier and snow monitoring in high mountain Asia, glacier and glacier lake inventories, future prospects of cryosphere monitoring. (3 hrs.)

Modelling the Climate System: Global and regional. (2 hrs.)

Energy balance modeling: Theory of surface energy balance basic fluxes and equations; the role of albedo; contrasted drivers of the surface energy balance in different regions, introduction to diurnal energy balance model (dEBM) model. (2 hrs.)

Machine Learning: Machine learning for cryospheric science. (2 hrs.)

Remote sensing: Introduction to software: ArcGIS, QGIS, Python; Data management; set up and installation, explore data, satellite data repositories and DEM searching and ordering. (2 hrs.)

xDEM: Introduction to xDEM processing in Python. (2 hrs.)

Practical

Image classification with band ratios in QGIS (clean ice and snow, vegetation, clouds, etc.) (SCP plugin in QGIS). (7 hrs.)

Glacier dynamics by Feature tracking: IMCORR plugin. (3 hrs.)

Terrain analysis: DEM pre-processing: clipping, re-projecting, merging, etc. (2 hrs.)

Hydrology data processing. (3 hrs.)

DEM co-registration with QGIS and XDEM. (6 hrs.)

Field glacier mass balance: point energy balance on glaciers, point mass balance, mass balance gradient, DGPS measurement and data processing. (2 hrs.)

Use of DEM to calculate glacier mass and volume change. (2 hrs.)

Processing climate models and reanalysis data (python); CRU and ISPL data; practical sessions (bash) with a python script to compute climate trends. (2 hrs.)

Automated image segmentation: Geo-SAM tool (QGIS plug-in). (2 hrs.)

Projects and Presentation (10 hrs.)

Course Title: Monsoon Meteorology **Credit Hrs:**

Course No: Hymet 667 **Lecture Hrs: 30**

Nature of the Course: Theory (Non-credit) **Full Marks:**

Semester: **Pass Marks:**

Course Contents:

Zonal Average Tropical Circulation: Introduction, zonal velocity, mean meridional circulations, temperature field, moisture field, meridional transports by zonally symmetric circulations. (4 hrs.)

Zonally Asymmetric Features of the Tropics: Introduction, gradient level winds, the moisture field in the upper troposphere, the temperature field, east west circulation in the tropics, the moisture field sea level pressure, other parameters. (3 hrs.)

Introduction of Monsoon: Definition, historical background features of the monsoon winds, a simple theoretical work of the monsoon, the differential heating that drives monsoon circulation, monsoon index. (4 hrs.)

Synoptic Component of the Monsoon: Role of ITCZ on monsoon circulation, dynamic thermodynamics of the monsoon, easterly waves, near equatorial monsoon trough, trans-equatorial flow, squall lines in the monsoon area, planetary scale monsoons, corresponding elements of winter and summer monsoon, easterly jet stream, different components of SW Indian monsoon. (4 hrs.)

Precipitation and Mesoscale Feature of the Monsoon: General features of monsoon rainfall; 100 years of monsoon rainfall; heat low, monsoon depressions, the monsoon inversion, on set of monsoon, withdrawal of monsoon, active and break monsoon, floods and drought trends of monsoon. (4 hrs.)

Climatological Features of Monsoon: Summary of mean climatological features, normal wind and pressure distribution, normal temperature, distributions. (3 hrs.)

March of the Seasons: Role of the Himalayan-Tibetan Massif in the monsoons during different seasons, general discussion of monsoon- equatorial Africa, Indonesia, Malaysian region, Indian Ocean, North Africa, Transition of circulation during autumn, winter, spring, early summer and summer season. (4 hrs.)

Walker Circulation: Elnino, Lanino, ENSO. (2 hrs.)

Monsoon in Nepal: Background, socio-economic effect, rainfall and wind characteristics, summer and winter monsoons in Nepal, Temporal and special domain of SW monsoon in Nepal, active and break situation during monsoon. (2 hrs.)

References

Das P. K. (1988), The Monsoon 2nd ed. National Book Trust, India.

Ramage. C. S. (1971), Monsoon Meteorology. Academic press New York and London.

Rao, Y. P. (1976), South West Monsoon. Meterological Monograph Synoptic Meteorology No. 1/1976 IMD. New Delhi.

Riehl, H. (1945), Tropical Meteorology. McGraw Hill Book Com. In. New York.

WMO, UNESCO (1965). Meterological Results of the int. Indian Ocean Expedition. Paris.

Course Title: Environmental Impact Assessment (EIA) **Credit Hrs:**

Course No: Hymet 668 **Lecture Hrs: 30**

Nature of the Course: Theory (Non-credit) **Full Marks:**

Semester: **Pass Marks:**

Course Contents:

Introduction: Background, basic concepts of EIA and sustainability, evolution of EIA, introduction of EIA into, Nepalese system, project types, impacts and their type, EIA process and project cycle, steps of EIA. (2 hrs.)

Introduction to Environment Management & EIA: Overview of key concepts in environmental science, including ecosystems, biodiversity, and environmental processes. (4 hrs.)

Legal, Policy & Regulatory Framework: Exploration of national and international environmental laws and regulations governing EIA processes. (4 hrs.)

Screening and Initial Environmental Examination (IEE): Objectives of screening, screening procedure, screening system in Nepal, BES and methods of conducting BES, Initial Environmental Examination, methods for IEE. (4 hrs.)

Scoping/Terms of Reference (TOR): Objective and approach, scooping requirements of Nepal, procedural and technical considerations, preparation of TOR and its main components. (4 hrs.)

Baseline Information for EIA Study: the environmental setting, purpose of baseline data, method of data collection, importance of baseline data, role of baseline information in monitoring process, role of baseline information in decision making. (4 hrs.)

Impact Identification and Mitigation Measures: Methods of impact identification, methods of impact prediction, impact evaluation techniques, numerical on impact prediction and evaluation, mitigation measures: introduction and objective, methods (alternatives, corrective, compensatory, preventive), implementation of mitigation measures. (4 hrs.)

Environmental Management Plan (EMP): Introduction and objective, environmental monitoring: introduction, methodologies, indicators, result and suggestion, environmental audit, environmental protection measures (EPMs), EIA report review and decision making. (4 hrs.)

References

ADB and ICIMOD. (2006). Environmental assessment of Nepal: emerging issues and challenges. Asian Development Bank and International Centre for Integrated Mountain Development, Kathmandu.

Barry, F. and Martha, K.F. (2012). Environmental economics. McGraw Hill Education, East Windsor.

Butlin, J.A. (1981). The economics of environmental and natural resources policy. West-view Press, Colorado.

Canter, L. W. (1999). Environmental Impact Assessment. CRC Press LLC.

ISO. (2004). International Standard ISO 14001, Reference no. 14001:2004 (E). International Organization for Standardization, Geneva.

Khadka, R.B. (1997). EIA training manual for professionals and managers. Asian Regional Environmental Assessment Program, IUCN, Kathmandu, Nepal.

NPC and IUCN. (1993). National environmental impact assessment guidelines. National Conservation Strategy Implementation Project, Kathmandu.

Upreti, B.K. (2003), Environmental Impact Assessment: Process and Practice, Publisher Mrs. Uttara Upreti, Kathmandu.

World Bank. (1991). Environmental assessment sourcebook: guidelines for environmental assessment of energy and industry projects, Vol.1II. Environment Department, The World Bank.

Course Title: Programming in Hydro-meteorology **Credit Hrs:**

Course No: Hymet 669 **Lecture Hrs: 30**

Nature of the Course: Theory (Non-credit) **Full Marks:**

Semester: **Pass Marks:**

Course Contents:

Introduction to Programming in Hydro-meteorology: Overview of programming languages (Python and R); Importance of programming in hydro-meteorological research; Setting up Python and R environments. (2 hrs.)

Basics of Python Programming: Python syntax, variables, and data types; Control structures: loops and conditionals; Functions and libraries in Python. (5 hrs.)

Basics of R Programming: R syntax, variables, and data types; Control structures: loops and conditionals in R; Functions and libraries in R. (5 hrs.)

Data Handling and Visualization with Python and R: Data manipulation with Pandas; Data visualization with Matplotlib and Seaborn; Data handling and visualization with R; Data manipulation with dplyr and tidyr; data visualization with ggplot2. (8 hrs.)

Statistical Analysis with Python: Statistical analysis using NumPy and SciPy; Introduction to statistical models and hypothesis testing in Python. (5 hrs.)

Statistical Analysis with R: Statistical analysis using built-in functions in R; Hypothesis testing, linear regression and other statistical methods in R. (5 hrs.)

References

Crawley M.J. (2007). The R Book. John Wiley and Sons Ltd., England, UK.

Crawley M.J. (2012). Statistical computing: an introduction to data analysis using R.

Mastrodomenico R. (2022). The Python Book. John Wiley & Sons, Inc.

Matthes E. (2015). Python Crash Course, 3rd Edition: A Hands-on, Project-Based Introduction to Programming, No Starch Press.

Course Title: Conflicts in Water Resources **Credit Hrs:**

Course No: Hymet 670 **Lecture Hrs: 30**

Nature of the Course: Theory (Non-credit) **Full Marks:**

Semester: **Pass Marks:**

Course Contents:

Introduction to Water Conflicts: Definitions and types of water conflicts, importance of water resources and potential for conflicts, overview of water governance and management. (4hrs.)

Local and Regional Water Conflicts: Case studies of local water disputes, community-based water management, stakeholder engagement and participatory approaches, regional water conflicts, cross-border water management challenges, regional cooperation and agreements. (8hrs.)

Transboundary Water Conflicts: Understanding transboundary water issues, international water law and treaties, case studies of successful and unsuccessful transboundary water management. (4hrs.)

Socioeconomic Factors in Water Conflicts: Water and social inequality, economic impacts of water scarcity, gender dimensions in water conflicts. (4hrs.)

Environmental Impacts and Climate Change: Water conflicts and environmental degradation, Climate change and its role in exacerbating water disputes, Sustainable water management in a changing climate. (4hrs.)

Conflict Resolution, Diplomacy and Future Trends: Negotiation strategies for water conflicts, Water diplomacy and its principles, Role of international organizations in conflict resolution. (6hrs.)

References

Parajuli, U., Miah, M., Rahman, K., Verghese, G., Mukherjee, S. and Hamid, S. (2004), Gloable Environment and Energy in the 21st Century, Honoluly, USA, 2004.

Salman, S. M. A. and Uprety, K. (2002), Conflict and cooperation on South Asia's international rivers: A legal perspective, The World Bank, Washington DC.

WECS. (2011). Water resources of Nepal in the context of climate change. Water and Energy Commission Secretariat, GoN, Kathmandu.

Course Title: Renewable Energy Resources **Credit Hrs:**

Course No: Hymet 672 **Lecture Hrs: 30**

Nature of the Course: Theory (Non-credit) **Full Marks:**

Semester: **Pass Marks:**

Course Contents:

Introduction: Definition of alternative energy, importance of alternative energy in the global energy mix, environmental and economic considerations. (2hrs.)

Solar Energy and Wind Energy: Solar radiation and its measurement, photovoltaic technology, solar thermal systems, applications and case studies, wind energy fundamentals, wind turbine technology, wind farm design and operation, integration into the power grid. (8hrs.)

Hydropower and Ocean Energy: Hydropower technologies and classifications, tidal and wave energy, ocean thermal energy conversion (OTEC). (4hrs.)

Biomass and Bioenergy: Biomass sources and conversion technologies, biofuels and their production processes, biogas and anaerobic digestion, environmental and social impacts. (4hrs.)

Geothermal Energy: Geothermal resources and exploration, geothermal power plants, direct use applications, enhanced geothermal systems (EGS). (4hrs.)

Energy Storage and Future Trends: Smart grids and the role of alternative energy, energy storage technologies, challenges and solutions for intermittent sources. (4hrs.)

Policy and Economics of Alternative Energy: Government policies and incentives, economic viability and cost analysis, life cycle assessment of alternative energy systems. (4hrs.)

References

Boyle, G. (2008). (Ed.). Renewable energy: power for sustainable future. Oxford University Press, New York.

Khan, B.H. (2006), Non-Conventional Energy Resources, Tata McGraw-Hill Publishing Company Limited, New Delhi.

Kothari, D.P., Singal, K.C., and Ranjan, R. (2009). Renewable energy sources and energy technology. PHI Learning Pvt. Ltd., New Delhi.

Mangal, B.S. (1999), Solar Power Engineering, Tata McGraw-Hill Publishing Company Limited, New Delhi.

Ristinin, R.A. and Kraushaar, J.J. (2006). Energy and environment. John Wiley and Sons Inc., New York.

UNDP/NPC. (1995). Prospective energy plan for Nepal. Perspective Energy Plan Project United Nations Development Programme and National planning Commission, Kathmandu.

WECS, 2010. Energy Synposis Report, Water and Energy Commission Secretariat, GoN, Kathmandu.

WECS. (1995). Alternative energy technology- overview and assessment. Water and Energy Commission Secretariat, GoN, Kathmandu.

Bridge Course for Non-meteorology Students

SN	Course Code	Course Name	Credits	Marks
1	Hymet.511	Applied Meteorology	4	100
2	Hymet 512	Applied Hydrology	2	50
		Total	6	150

Course Title: Applied Meteorology **Credit Hrs: 4**

Course No: Hymet 511 **Lecture Hrs: 60**

Nature of the Course: Theory (Bridge Course) **Full Marks:**

Semester: I **Pass Marks:**

1. **General Meteorology**
   a. **Atmospheric Composition, Mass and Structure:** Total atmosphere, Variations with height, Variations with latitude and season, Variations with time.
   b. **Vertical Structure of the Atmosphere:** Troposphere, Stratosphere, Mesosphere, Thermosphere, Exosphere and magnetosphere.
   c. **Solar Radiation and the Global Energy Budget:** Solar radiation, Solar output, Distance from the sun, Altitude of the sun, Length of day.
   d. **Atmospheric Energy and Horizontal Heat Transport:** The horizontal transport of heat, Spatial pattern of the heat budget components.
   e. **Atmospheric Stability:** Atmospheric instability, cloud formation and precipitation processes
   f. **General Circulation:** Circulations in the vertical and horizontal planes, Variations in the circulation of the northern hemisphere
2. **Climatology:**
   a. **Introduction to the Climate System:** Atmosphere, Ocean and land surface, atmospheric temperature, atmospheric composition, weather and climate, Definition and scope of climatology, sub-division of climatology, Factors affecting climate.
   b. **Classification of Climate, their Type and Distribution:** Need and objectives of classification, basis of classification, Koppen's classification, Thornthwaites classification
   c. Climate of Nepal: East-West variation, orographic variation, western disturbances, Convection in pre and post-monsoon, summer monsoon**.**
3. **Physical Meteorology**
   a. **Equation of State**: Variable of state, Derivation of Charles' Law and Boyle's Law, equation of state of an ideal gas, mixture of gases

b. **Heat and Energy:** specific heat capacity, internal energy, conservation of energy, adiabatic processes, Poisson's equation, entropy and the second law of thermodynamics, Thermodynamics of moist air (equation of state of moist air, changes of phase and latent heat, The Clausius-Clapeyron equation,

c. **Moisture Variable:** Brief introduction of vapor pressure, absolute humidity, mixing ratio, specific humidity, relative humidity, virtual temperature, dew point temperature, lifting condensation level (LCL), wet-bulb temperature, wet-bulb potential temperature, equivalent temperature and equivalent potential temperature.

d. **Hydrostatic Equilibrium:** Hydrostatic equation, hydrostatic of special atmosphere (the homogenous atmosphere, the isothermal atmosphere, the constant lapse rate atmosphere, the dry adiabatic atmosphere and the US standard atmosphere

e. **Hydrostatic Stability and Convection**: Dry and moist adiabatic lapse rate, the parcel method, the slice method.

4. Synoptic and Aviation Meteorology

a. **Definition and Scope of Synoptic Meteorology:** Synoptic scale, synoptic hours, surface weather map analysis.

b. **Air mass and Fronts**: Introduction, Area of formation and classification, Cold and warm air masses, Continental and maritime air masses, Air mass modification, fronts.

c. **Monsoon:** Introduction- southwest monsoon and northeast monsoon, Differential heating theory, Migration of ITCZ, Monsoon vagaries: Onset of monsoon and its importance associated with it, Onset criteria, Trough and weather associated with it, Depression and its movement, Break/active monsoon and its synoptic situation, Withdrawal of monsoon

d. **Western Disturbances:** Introduction and formation, Synoptic situation during the formation of WD, Movement of WD and weather associated with it

e. **Aviation Meteorology**: Atmospheric pressure and its relationship with flight (QFE, QFF, QNH., etc.).

f. **Turbulence, Icing and Aviation Hazards:** Low-level and high-level turbulence (CAT), thunderstorm and turbulence associated with it, airframe icing and aviation hazards, Meteorological services and flight planning

5. Micrometeorology

a. **General Introduction:** Introduction micrometeorology, definition of surface boundary layer, relation between micrometeorology and microclimatology, scope of micrometeorology.

b. **Net Radiation:** Calculation and measurement of long wave radiation on the earth surface, definition of emissivity, introduction of greenhouse effect, measurement of short-wave radiation from the atmosphere, definition of net radiation, measurement of all wave net radiation, total heat balance on the Earth's surface, conversion of mass flux into energy flux.

c. **Ground Heat Flux and Temperature:** Surface air temperature, temperature variation on the earth's surface, soil temperature, temperature gradient and rate of temperature variation, derivation of ground heat flux at land surface, conduction of heat flux into the soil layer and determination of soil conductivity, soil moisture and its measurement, surface moisture and its measurement, soil moisture saturation process, relative humidity and specific humidity.

d. **Evaporation:** Evaporation from the earth surface, estimation of evaporation, measurement of temperature and relative humidity, relation between relative humidity and saturation vapor pressure, daily, monthly and seasonal variation of evaporation

6. Dynamic Meteorology

a. **Atmospheric Coordinates:** Inertial (absolute, fixed, non-rotating) and non-inertial (relative, moving, rotating) frame of references, geocentric reference frame, Cartesian and spherical coordinates, height, pressure and potential temperature as vertical coordinates, Lagrangian and Eulerian control volume, natural coordinates, generalized vertical coordinate.

b. **Conservation of Momentum**: Newton’s first law of motion, the vectorial form of the momentum equation in rotating coordinates, the component equations in spherical coordinates, scale analysis of equations of motion.

c. **Conservation of Mass:** Lagrangian and Eulerian derivations and scale analysis of equation of motion.

d. **Basic Equations:** Basic equations in height and pressure coordinates (horizontal momentum, continuity, and thermodynamic energy equations).

7. Atmospheric Pollution and Climate Change

a. **The Atmosphere:** The atmospheric boundary layer, local wind structure, stability criteria, plume behavior, logarithmic profile, the Ekman spiral, turbulence, boundary layer scaling.

b. **Pollutant and their Properties**: Major source of gases (CO_2, SOx, NOx) and their residence time, physical chemical and optical properties of aerosol. Stratospheric aerosol, chemical component of tropospheric aerosol, size of atmospheric pollutant, CCN

c. **Dispersion of Pollutants:** Statistical theories of pollutant diffusion, Gaussian plume model, plume rise, effective stack height

d. **Climate Change**: Introduction, global carbon cycle, global carbon budget, feedback of global climate, direct and indirect impact of aerosol, role of IPCC in climate change.

e. **Climate Change Impacts:** Climate change impacts on water resources, bio-diversity, Agriculture, human health, socio-economy, coastal area etc.

References

Ahrens, C.D. 2003. *Meteorology Today, 7th Edition*. Brooks Cole.

Albright John G., Physical Meteorology, Prentice Hall Inc., New York.

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Hess S.L. (1959), Introduction to Theoretical Meteorology, Holt Rinehart and Winston, New York.

Holton J. R., (1992), An Introduction to Dynamic Meteorology, Academic Press Inc., New York.

Krishnamurti, T.N. (1979), Compendium of Meteorology Vol. II Part 4, TYropical Meteorology, WMO Publication No. 364, Geneva.

Pandharinath, N. (2007), The Science of Weather and Environment, B S Publications, Hyderabad.

Petterssen, S. (1956), Weather Analysis and Forecasting Vol I & II, Mc Graw Hill Company Inc. New York.

Ramage, C.S. (1971), Monsoon Meteorology, Academic Press, New York.

Course Title: Applied Hydrology **Credit Hrs: 2**

Course No: Hymet 512 **Lecture Hrs: 30**

Nature of the Course: Theory (Bridge Course) **Full Marks:**

Semester: I **Pass Marks:**

1. **Introduction:** Definition, and scope of hydrology**,** hydrological cycle and water balance equations**,** development of hydrological study and hydrometric networks in Nepal
2. **Catchment Characteristic:** Stream pattern, drainage, slope, shape, altitude, stream length, catchment area, drainage density, relief, stream density and stream order, hypsometric curve, area length relation, river basin of Nepal.
3. **Hydrological Analysis:**
   a. **Precipitation**: Causes, forms, and types of precipitation, measurement of rainfall, network design, estimation of missing data, double mass curve, computation of average rainfall, optimum number of rainfall stations, status of precipitation measurement in Nepal.
   b. **Hydrological Losses:** Initial losses, evaporation process meteorological parameters energy budget methods and mass transfer approach (Dalton's law), evapotranspiration, potential evapotranspiration, infiltration, factors affecting infiltration, Horton's equation, infiltration indices.
   c. **Surface Runoff:** Drainage basins and its quantitative characteristics, factors affecting runoff from a catchment, Rainfall-Runoff relationship.
   d. **Hydrograph:** Hydrograph concept, factors affecting of hydrograph and shape of hydrograph, component of hydrograph, base flow separation, effective rainfall, theory of unit hydrograph, assumption, uses and limitation of unit hydrograph, derivation of unit hydrograph.
   e. **Groundwater:** Introduction, occurrence of groundwater, types of aquifers, aquifer parameters, groundwater basin, Darcy's law its range validity, field measurement of permeability, yield of dug well, artificial groundwater recharge, concept of springshed, and hot springs.

f. **River Flow Analysis:** peak discharges, river regimes, flow frequency, flood frequency, flood prediction, rainfall-runoff relationships: rational method, catchment area method.

4. **Measurement of Stage:** Definition, nonrecording water level recorder, recording gauge, data logger, crest gauge and its importance, benchmark, flood mark, stage hydrograph, estimation of missing stage data, network design stage measurement practices in Nepal, hydrological network of Nepal.
5. **Measurement of Discharge and Station Calibration**: Definition, direct method- area velocity, calculation of area and mean velocity, vertical velocity distribution, wading, cableway, bank operating and bridge under measurement method, types of current meter, calibration of current meter, sounding weights, adopted procedures for discharge measurement, indirect method, roughness coefficients, estimation of peak flow, hydraulic structures, notch, weirs, flume, station calibration: stage discharge relation, controls, extension and interpolation of rating curves rating table, validation of rating curves.
6. **Erosion and Sedimentation:** Erosion and sedimentation, types of erosion, sources of sediment, control measure of sedimentation, factors affecting sediment yield, suspended and bed sediment load measurement and analysis.
7. **Engineering Applications:**
   a. **Design Floods:** Introduction, different method of flood estimation, regional flood frequency studies, design flood.
   b. **Hydropower:** Hydropower potential of Nepal, types and classification of hydropower and their arrangements, estimation of hydropower, firm power and secondary power, current demand and load forecast in Nepal
   c. **Municipal/Rural Water Supply:** Municipal/rural water supply demand, distribution system, methods of supplying water, status of municipal/rural water supply in Nepal.
   d. **Irrigation:** Classification and types of irrigation, irrigation system, methods of irrigation, crop water requirement, potential and status of irrigation facility in Nepal
   e. **Urban Hydrology**: Climate modifications, catchment response modifications, urban development planning, drainage design, flood protection, conservation, disposal of surface water.

f. **River Basin Management**: Introduction, Classification of rivers, behavior of river, river regime theory, human use of rivers, hazards due to rivers, River Training, objectives of River Training, planning of River Training works, type of River Training, design parameters.

References

Chow, V.T., Maidment, D. R. and Mays, L. W. (1988), Applied Hydrology, McGraw-Hill International Editions.

Mutreja, K.N. (1986), Applied Hydrology, Tata McGraw-Hill Publication Company Limited.

Raghunath, H.M. (2006), Hydrology Principles, Analysis, Design; revised 2nd edition, New Age International Publications.

Subramanya, K. (2008), Engineering Hydrology, 3rd edition, Tata McGraw-Hill Publication Company Limited.

Todd, D.K. (1995), Groundwater Hydrology, Second Edition, John Wiley & Sons.

Dissertation Research

The creation of research is an integral part of all the degree being offered at Central Department of Hydrology and Meteorology, Tribhuvan University (CDHM). This includes building the capacity of the graduates to design significant and original research problems. Students should also acquire the literary skills necessary to conduct and communicate that research to other scholars as well as the concerned stakeholders. CDHM considers the preparation of a dissertation an important avenue through which these skills are acquired.

The preparation of a consistent and comprehensive research proposal is an integral part of the dissertation work, carried out individually, under supervision of potential supervisor. The candidate must pay proper attention to the research proposal, since the dissertation should be based on primary data either generated from the field or laboratory or both. A dissertation completed by analysis of only secondary data will not be accepted or allowed to submit. The candidate should submit his/her research proposal within the stipulated deadline. The candidates are not allowed to start their dissertation research without a prior approval of the detailed research proposal.

During the research period, the candidates are expected to participate in the activities like seminar presentations by fellow-candidates, guest lectures and scientific discussions organized by the CDHM. The candidates are also encouraged to participate and present their work in national/international conferences, workshops and symposia.

The detail credit allocation framework of the dissertation is as outlined below:

SN	Evaluation Scheme	Credit (hrs.)	Marks
1	Dissertation Proposal Seminar	1	25
2	Mid-term Progress Presentation	2	50
3	Manuscript	1	25
4	Final Report and Presentation	4	100
Total		**8**	**200**

Seminar of the Research Proposal

After the registration at CDHM, the candidate has to defend the dissertation proposal in a seminar, organized by CDHM. During the seminar, the dissertation proposal will be evaluated by the team of experts and finally approved by the Central Departmental Research Committee (CDRC). The

committee reserves the right to reject or ask for re-submission of the proposal on the following condition (s):

- The topic is inappropriate (does not significantly include issues pertaining to the M.Sc. in Hydrology and Meteorology),
- It is wholly or largely duplicates work previously undertaken,
- The topic is unfocused and ill-specified (too broad, too general or too vague), and
- Unavailability of proposed subject expert for supervision

Mid-term Progress Report

The candidate has to submit and present the progress report in an open presentation explaining all the activities and achievements made so far. The date/time for the progress report submission and mid-term presentation will be notified by the department; it is usually after three months of the fourth semester.

Manuscript

The CDHM is very much committed in producing peer-reviewed research papers out of the students' dissertations. Students will be asked to prepare at least one manuscript from the dissertation to submit along with the final dissertation report for evaluation. Students may use Journal *Jalawaayu* guidelines while preparing the manuscript or may publish their works in national/international journal/s.

Final Report and Presentation

Students have to prepare their final dissertation in the prescribed format of the CDHM for final evaluation and presentation. The final report must be signed duly by the respective supervisor/s. Students will be notified of the date of the defense/viva voce /examination of the dissertation. During the presentation, each member of the Dissertation Evaluation Committee (DEC) may ask question(s). The dissertation coordinator (faculty member) of CDHM or the internal examiner will facilitate the defense programs and the question sessions. During the final evaluation, every component of the dissertation will be discussed. A dissertation evaluation sheet will be provided for the final evaluation. All the members of the evaluation committee will evaluate the candidate during the defense. By compiling the independent and confidential scores given by the expert members, the DEC will make a recommendation whether the dissertation has been accepted.