CURRICULUM

OF

WATER MANAGEMENT

FOR

BS/B.Sc (Hons)

MS/M.Sc (Hons)

Ph.D

(Revised 2010)

HIGHER EDUCATION COMMISSION
ISLAMABAD

CURRICULUM DIVISION, HEC

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PREFACE

The curriculum of subject is described as a throbbing pulse of a nation. By viewing curriculum one can judge the stage of development and its pace of socio-economic development of a nation. With the advent of new technology, the world has turned into a global village. In view of tremendous research taking place world over new ideas and information pours in like of a stream of fresh water, making it imperative to update the curricula after regular intervals, for introducing latest development and innovation in the relevant field of knowledge.

In exercise of the powers conferred under Section 3 Sub-Section 2 (ii) of Act of Parliament No. X of 1976 titled **"Supervision of Curricula and Textbooks and Maintenance of Standard of Education"** the erstwhile University Grants Commission was designated as competent authority to develop review and revise curricula beyond Class-XII. With the repeal of UGC Act, the same function was assigned to the Higher Education Commission under its Ordinance of 2002 Section 10 Sub-Section 1 (v).

In compliance with the above provisions, the HEC undertakes revamping and refurbishing of curricula after regular intervals in a democratic manner involving universities/DAIs, research and development institutions and local Chamber of Commerce and Industry. The intellectual inputs by expatriate Pakistanis working in universities and R&D institutions of technically advanced countries are also invited to contribute and their views are incorporated where considered appropriate by the National Curriculum Revision Committee (NCRC).

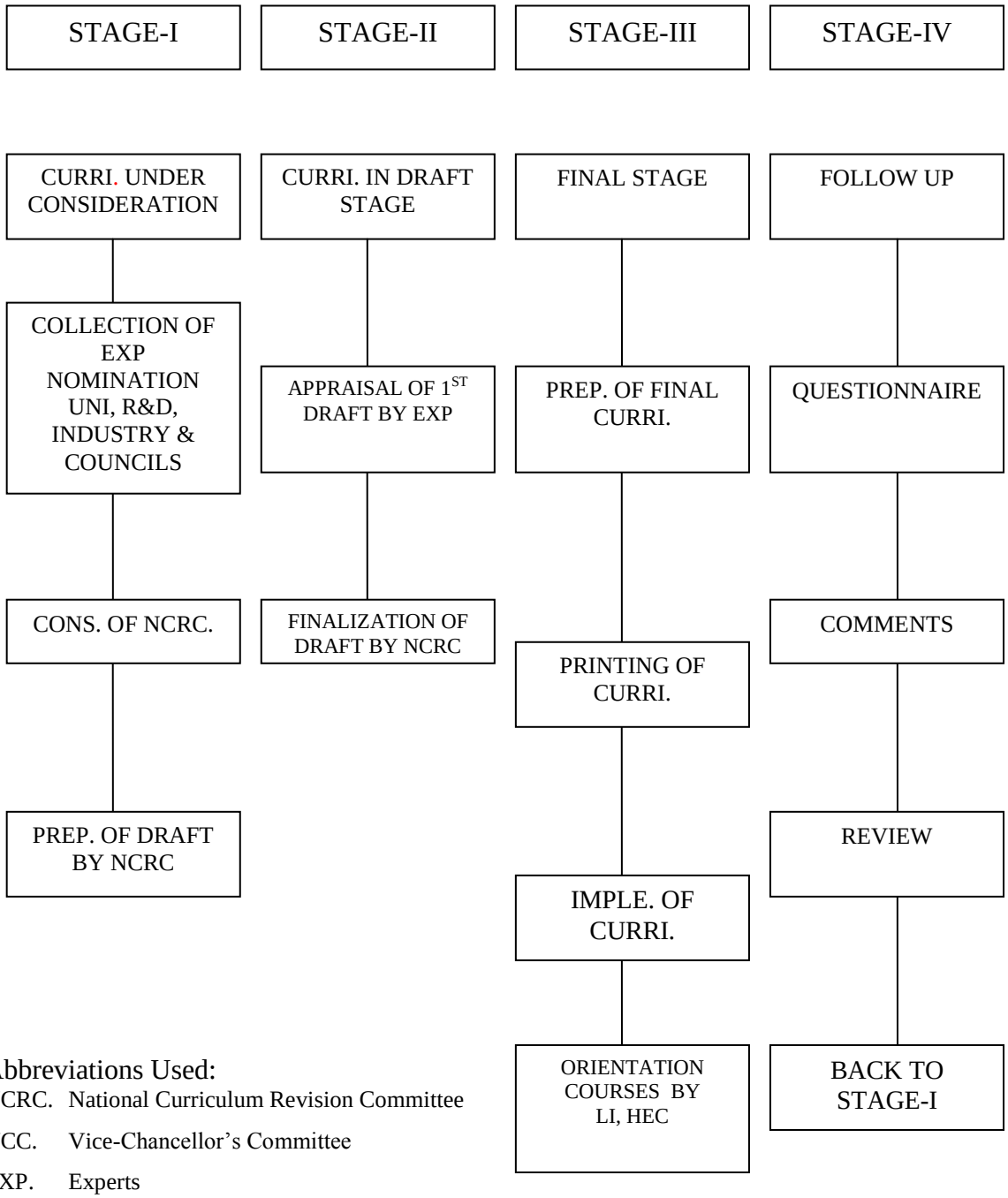
To bring international compatibility to qualifications held from Pakistani universities/DAIs for promotion of students mobility and job seekers around the globe, a Committee comprising of Conveners of the National Curriculum Revision Committee of HEC met in 2009 and developed a unified template for standardized 4-years/8-semesters BS degree programmes. This unified template was aimed to inculcate broader base of knowledge in the subjects like English, Sociology, Philosophy, Economics etc in addition to major discipline of study. The Bachelor (BS) degree course requires to be completed in 4-years/8-semesters, and shall require qualifying of 130-140 credit hours of which 77% of the curriculum will constitute discipline specific and remaining 23% will comprise compulsory and general courses.

In line with above, NCRC comprising senior university faculty and experts from various stakeholders and the respective accreditation councils has finalized the curriculum for BS and MS (Water Management). The same is being recommended for adoption by the universities/DAIs channelizing through relevant statutory bodies of the universities.

PROF. DR. ALTAF ALI G. SHAIKH
Member Academics

March 2010

CURRICULUM DEVELOPMENT



Abbreviations Used:

NCRC. National Curriculum Revision Committee

VCC. Vice-Chancellor's Committee

EXP. Experts

COL. Colleges

UNI. Universities

PREP. Preparation

REC. Recommendations

LI Learning Innovation

R&D Research & Development Organization

HEC Higher Education Commission

INTRODUCTION

The National Curriculum Revision Committee final meeting was held on March 1-3, 2010 at Higher Education Commission Regional Centre, Karachi to finalize the draft curriculum in Water Management at graduate and postgraduate level developed in its preliminary meeting held on November 16-18, 2009. The following experts attended the meetings:

1. Prof. Dr. Tahir Sarwar, — Convener
   Department of Water Management,
   Khyber Pakhtun Khaw Agriculture University,
   Peshawar

2. Mr. Olass Khan, — Member
   Director General,
   On-Farm Water Management,
   Khyber Pakhtun Khaw, Peshawar

3. Prof. Dr. Ihsan Ilahi, — Member
   Dean,
   Faculty of Sciences
   Karakoram International University,
   Gilgit

4. Prof. Dr. Maqsood Ahmad, — Member
   Chairman,
   Department of Environmental Management and Policy,
   Baluchistan University of Information Technology, Engineering & Management Sciences (BUITEMS),
   Quetta

5. Prof. Dr. Mushtaq Hussain Kazmi, — Member
   Chairman,
   Department of Agronomy,
   Faculty of Agriculture,
   Azad Jammu & Kashmir University,
   Rawalakot

6. Prof. Dr. Allah Bakhsh, — Member
   Department of Irrigation & Drainage,
   University of Agriculture,
   Faisalabad

7. Prof. Dr. Muhammad Saffar Mirjat, — Member
   Chairman,
   Department of Irrigation & Drainage,
   Sindh Agricultural University
   Tandojam

8. Prof. Dr. Tariq Masood Ali Khan, Member
Institute of Environmental Studies,
University of Karachi,
Karachi

9. Dr. Altaf Ali Siyal, Member
Associate Professor,
Department of Land and Water Management,
Sindh Agriculture University,
Tandojam

10. Engr. Iqbal Zeb Khattak, Member
Faculty of Agriculture,
Gomal University,
Dera Ismail Khan

11. Dr. Abdullah Yasar, Member
Assistant Professor,
G.C. University,
Lahore

12. Mr. Tahir Mehmood, Member
Coordinator,
Pakistan Wetland Program (UNDP),
Islamabad

13. Mr. Muhammad Jamshed Iqbal, Member
Wetlands Biologist,
Pakistan Wetland Program (UNDP),
Islamabad

14. Mr. Khan Ghulam, Member
Manager (Water Resources),
Mass Awareness for Water Conservation &
Development Project,
Pakistan Council of Research in Water
Resources (PCRWR),
Islamabad

15. Mr. Asif Javed, Member/Secretary
Senior Lecturer,
Department of Earth and Environmental
Sciences,
Bahria University,
Islamabad

Proceedings of the Preliminary Meeting (November 16-18, 2009)

Meeting started with recitation from the Holy Quran by Mr. Olass Khan. Prof. Dr. Altaf Ali G. Sheikh, Member (Academics), Higher Education Commission, welcomed and briefed the committee about the responsibility of the Commission for revision of curricula of all subjects taught at graduate and post graduate level in the universities and Degree Awarding Institutes in the country.

The Committee unanimously selected Dr. Tahir Sarwar as Convener and Mr. Asif Javed as Secretary. Dr. Tahir Sarwar briefed the committee about the curriculum revision which took place in 2003 and appreciated the efforts of previous committee. He made clarification that previous curriculum was developed for Bachelor of Engineering with specialization in Water Management, which could not be implemented due to the uniqueness of the programme and recognition problem with the Pakistan Engineering Council (PEC) and Government organizations. He suggested that existing Water Management curriculum already being taught at BSc. (Hons)/MSc (Hons)/PhD in Agriculture with specialization in Water Management should be revised. While discussing the matter of overlapping of Agricultural Engineers and Water Management graduates for competition in jobs, Prof. Dr. Altaf Ali G. Sheikh pointed out that sometimes there is an overlap in different degree programmes but one cannot negate the importance of other. He advised the committee that the curriculum in Water Management should be revised keeping in view the national interest rather that interest of the individual universities.

The Committee revised the curriculum for graduate and postgraduate degree programmes which was sent to all the committee members for comments and suggestions. Draft curriculum was finalized in the next meeting.

At the end of meeting, Dr. Tahir Ali Shah, Deputy Director (Curriculum), HEC, thanked the committee members for their valuable time and suggestions especially the participants from the R&D organizations.

Proceedings of the Final Meeting (March 1-3, 2010)

Meeting started with recitation from the Holy Quran by Dr. Altaf Ali G. Sheikh, Member (Academics), Higher Education Commission. He welcomed the participants and appreciated their efforts in preparing the draft curriculum. He showed satisfaction over the comments received from the international reviewers: Dr. Masoud Edraki, Senior Lecturer, Surface Hydrology, and Dr. Muhammad Nadeem Asghar, Senior Lecturer, Environmental Hydrology, Charles Sturt University, Australia, on the draft curriculum prepared in the preliminary meeting. He requested the committee to finalize the draft as per template/framework developed by Deans/Conveners of National Curriculum Revision Committee in the discipline of Agriculture.

Dr. Tahir Sarwar, Convener, National Curriculum Revision Committee in Water Management, thanked the committee for the time and effort in preparing the draft curriculum. He requested the members to carefully go through the draft and comments of expatriate Pakistani expert for incorporation in the final draft curriculum.

Dr. Sarwar appreciated the comments received by the international reviewers. He informed that international reviewers acknowledged the role and significance of water management specialization in the degree of agriculture both at graduate and postgraduate level. The expatriate experts stressed that both engineering and management disciplines are important in addressing the issues of today and future, our agriculture is facing. They suggested that careful revision is needed to include courses related to rainfed agriculture also to make the post-graduate degree curriculum distinct and advanced from the graduate degree curriculum. They further suggested to make a balance between the classic reference books and recently published easy-to-understand and glossy style text books. For the post-graduate degree programme, they pointed out the need to include a subject on the philosophy of science in research of water management.

The committee finalized the draft curriculum of water management at graduate and post graduate level in the light of suggestions/comments received from the NCRC members and expatriate Pakistani experts. At the end of meeting, Dr. Tahir Ali Shah, Deputy Director (Curriculum), HEC, thanked the committee members for their valuable time and suggestions especially the participants from the R& D organizations.

Rationale

Water management can be defined as the planned development, distribution and use of water resources in accordance with predetermined objectives while respecting both the quantity and quality of the water resources. It is the specific control of all human interventions concerning surface and ground water. Every planning activity relating to water can be considered as water management in the broadest sense of the term (ICID, 2000).

Many regions of the world are increasingly facing challenges when it comes to managing water. Although all challenges are related to water, the nature of the challenge differs from one location to the next. It may relate to having too little water while water demands are growing explosively (water scarcity), too much water (flooding), water of poor quality rendering them unfit to sustain the ecosystem or challenges related to providing water for people, industry and agriculture. What complicates matters further is that these challenges are all interdependent and influence each other. For example, water scarcity can impact water quality and the ability to provide water. Addressing these challenges requires that water managers apply an integrated and interdisciplinary approach,

involving hydrological, biophysical, chemical, economic, institutional, legal, policy-making and planning aspects.

The programme focuses on scientific analysis of the physical, technical and socio-economic aspects of water management and on the ability to design sustainable and efficient technical solutions to water management problems. Students in the programme develop comparative insight into the development of water management, take a scientific approach to various research paradigms and acquire a problem-oriented, interdisciplinary attitude towards land and water management and rural development issues. The programme addresses issues such as water resources management and the relationship between the hydrological cycle and agriculture. Management interventions for the conservation of soil and water and the maintenance of natural resources in sustainable farming are an integral part of water management degree programme. Socio-economic disciplines are integrated with technical aspects.

Goal/Aim:

Water Management degree programme provides the appropriate science and technology background required to manage water effectively and efficiently for agriculture. The common themes are the scientific assessment of plant water requirements and water resources, and the management of efficient irrigation systems.

On successful completion of the degree students will be able to:

- Implement and operate appropriate and sustainable solutions to irrigation and agricultural water management, with due regard to the technical, social and institutional constraints imposed by the surrounding environment;

- Assess crop water needs and plan for sustainable and efficient use of water resources;

- Have understanding of the physical water system and be able to predict and describe the impacts that human activities can have on the water and environmental resources

- Be able to explain principles, concepts and instruments of water resources and common and desired institutional and management arrangements

- Be able to model processes of water allocation and use at different scales, and interpret model outcomes in order to gain an understanding of problems, trends, causes and effects.

Curriculum for B.Sc. (Hons) Agriculture with Specialization in Water Management :

i. General Objectives of the Programme

B.Sc (Hons) programme in Water Management provides the basic science and technology background required to manage water effectively and efficiently for agriculture. The common themes are the scientific assessment of plant water requirements and water resources, and the management of efficient irrigation systems.

ii. Learning Outcomes of B.Sc. (Hons) Programme

On successful completion of this programme students will be able to:

Implement and operate appropriate and sustainable solutions to irrigation and agricultural water management, with due regard to the technical, social and institutional constraints imposed by the surrounding environment;

- Assess crop water needs and plan for sustainable and efficient use of water resources;
- Operate and manage pumps, conveyance and application systems; and
- Manage and schedule irrigation systems effectively and sustainably.

iii. Scheme of Studies for B.Sc. (Hons) Programme

Template for 4-Year BS/B.Sc (Hons) in Agriculture Disciplines

1. Compulsory Courses

	Credit Hours
Mathematics / Biology	6 (3-0) (2-1)
Statistics 1 & 2	6 (3-0) (3-0)
Computers / IT	3 (2-1)
Pak Studies	2 (2-0)
Islamiat	2 (2-0)
Communications Skills	3 (3-0)
English	3 (3-0)
Basic Agriculture	3 (2-1)
Sub-Total	**28**

2. Interdisciplinary Foundation Courses

Agronomy	3 (2-1)
Plant Breeding & Genetics	3 (2-1)
Entomology	3 (2-1)
Plant Pathology	3 (2-1)
Food Technology	3 (2-1)
Horticulture	3 (2-1)
Soil Sciences	3 (2-1)
Agriculture Economics	3 (2-1)
Sub-Total	**24**

3. Supporting Courses (6-8 Courses (3 Cr.hr) amongst below)

Agriculture Extension
Forestry & Range Management
Animal Science
Marketing & Agri Business
Rural Development
Human Nutrition
Agriculture Chemistry
Agriculture Engineering
Water Management
Any other discipline recommended by the university

Sub-Total	**18-24**

Sub-Total during the first four semesters	**70 - 76**
Semester 5, 6, 7 & 8	**56 - 60**
Project / Internship	**04**
Grand Total	**130 - 140**

- 1 credit of theory = one contact hour per week for 16-18 weeks and 1 practical/Lab hour = 3 contact hours per week for 16-18 weeks.

- In case of non availability of department of supporting courses, courses from foundation courses can be opted.

SCHEME OF STUDIES
For BS/BSc (Hons) in Water Management

Course No.	Course Title	Credit Hrs
	FORTH SEMESTER	
WM-001	Fundamentals of Water Management	3 (2-1)
	FIFTH SEMESTER	
WM-002	Soil, Plant and Water Relations	3 (2-1)
WM-003	Hydraulics	3 (2-1)
WM-004	Surveying and Leveling	3 (2-1)
WM-005	Hydrology	3 (2-1)
WM-006	Water Quality	3 (2-1)
	SIXTH SEMESTER	
WM- 007	Irrigation System	3 (2-1)
WM- 008	Hydrometry	3 (2-1)
WM-009	Irrigation Scheduling	3 (2-1)
WM-010	Watershed Management	3 (2-1)
WM-011	Agricultural Meteorology	3 (2-1)
	SEVENTH SEMESTER	
WM-012	Surface Irrigation	3 (2-1)
WM-013	Participatory Water Management	3 (2-1)
WM-014	Water Supply and Sanitation	3 (2-1)
WM-015	Water Wells and Pumps	3 (2-1)
	EIGHTH SEMESTER	
WM-016	Pressurized Irrigation	3 (2-1)
WM-017	Agricultural Drainage	3 (2-1)
WM-018	Irrigation Scheme Development	3 (2-1)
WM-019	GIS and Remote Sensing	3 (2-1)
WM-020	Project/Internship	4 (0-4)

DETAIL OF COURSES FOR BS/B.Sc (HONS)
WATER MANAGEMENT

FORTH SEMESTER

WM-001 **FUNDAMENTALS OF WATER MANAGEMENT** 3 (2-1)

OBJECTIVE:
To provide knowledge of the basic concepts of water management and its role in agriculture

THEORY:
Introduction: concept of water management; its importance; goals and objectives; hydrologic cycle; sources of irrigation water; units of measurement. Climate and weather: weather elements and their measurement; effect of weather elements on plant growth; agro-climatic zones of Pakistan. Irrigation scheduling: components of irrigation scheduling, soil-water-plant relations; soil moisture; types of soil moisture; soil moisture constants; water requirements of crops; irrigation efficiencies. Irrigation Systems: components of irrigation system; Indus basin irrigation system; irrigation system management; water distribution schedules; spate irrigation. Irrigation methods: surface irrigation; basin, border, furrow irrigation and pressurized irrigation; sprinkler and trickle irrigation; adoptability and limitations: groundwater: aquifer; types of aquifer; properties of aquifers; groundwater movement; groundwater recharge: water management in rainfed areas

PRACTICAL:
Determination of soil moisture by different methods; visit to a meteorological station; determination of soil moisture constants; saturation capacity; field capacity; wilting point and available water; visit to an irrigation scheme; flow measurement by different methods.

BOOKS RECOMMENDED:

1. Choudhary, M. R., 2009. A Text Book of Irrigation and Drainage Practices for Agriculture. University of Agriculture, Faisalabad.
2. Biswas, A. K. C. Tortajada, and R. Izquierdo-Avino. 2009. Water Management in 2020 and Beyond (Water Resources Development and Management). Springer, Heidelberg, Germany.
3. Kahlown, M. A. and A. Majeed. 2004. Pakistan Water Resources Development and Management. Pakistan Council of Research in Water Resources, Ministry of Science and Technology, Government of Pakistan.
4. Micheal, A. M. 2003. Irrigation Theory and Practices. Vikas Publishing House (Pvt), New Delhi.
5. Faruqui, N. I. A. K. Biswas, and M. J. Bino. 2000. Water Management in Islam. United Nations University Press, Tokyo.
6. De bont, Michael. 1993. Water in Agriculture. Department of Water Management, NWFP Agricultural University, Peshawar.

7. Ahmad, N. 1993. Water Resources of Pakistan, Shahzad Nazir, 61 B/2, Gulberg , III, Lahore.

FIFTH SEMESTER

WM-002 **SOIL, PLANT AND WATER RELATIONS** 3 (2-1)

OBJECTIVE:

To provide an understanding of basic plant-water-soil relationships and factors effecting crop water use

THEORY:

Introduction: importance, structure and properties of water, functions of water. Soil water potential: concept of water potential; units of water potential. Soil-water relation: soil properties like three phase system; texture and structure; forces and potentials of soil water; soil moisture-tension relationship; field capacity; wilting point; available water; measurement of soil moisture and potential: Movement of water; infiltration; redistribution of infiltrated water and evaporation: Plant-water relation; plant processes; rooting characteristics; effective root depth; how do plants get water; movement of water in stem; leaf as controlling apparatus. Atmosphere-water relation: Atmosphere as source of energy; potential evapotranspiration ETo; climatological factors influencing ETo. Movement of water through soil-plant-atmosphere system: water uptake by root-systems from soil; water release by plant to atmosphere; effects of salts.

PRACTICAL:

Taking soil samples disturbed/undisturbed; determination of water content; determination of soil moisture retention curve; determination of infiltration rate; measuring soil moisture tension/potential.

BOOKS RECOMMENDED:

1. Kirkham, M. B. 2005. Principles of Soil and Plant Water Relations. Elsevier Academic Press, Burlington.
2. Micheal, A. M. 2003. Irrigation Theory and Practices. Vikas Publishing House, New Delhi.
3. Gupta, O. P. 2002. Water in Relation to Soils and Plant. Agrobios, Jodhpur.
4. Ministry of Food, Agricultural & Livestock. 1996. On-Farm Water Management Field Manual: Vol. I (Reference). Water Management Wing, Government of Pakistan. Islamabad.
5. Kramer, P. J., J. S. Boyer. 1995. Water Relations of Plant and Soils. Academic Press, London.

OBJECTIVE:

To provide and understating of hydraulics principles and how they apply to irrigation systems. This course exposes the student to an expansive suite of topics and methods within the field of hydraulics, hydrologic and hydraulic concepts

THEORY:

Introduction: definition; fluid; pressure; mass; density; specific gravity; viscosity; surface tension and capillarity. Fluid statics: pressure density-height relationship; absolute and gauge pressure; forces on submerged plane; static stability; Buoyancy of flotation. Fundamentals of fluid flow: concepts of water flow regime; continuity equation; energy equation; velocity head, kinetic energy, pressure energy, potential and elevation energy; application of Bernoulli's equation; energy grade line; hydraulic grade line. Pipe flow: laminar flow; critical velocity; Reynold's number; Froude number, turbulent flow; velocity distribution; Darcey-Weisbach formula; fraction factor. Open channel flow: difference between pipe flow and open channel flow; hydraulic parameters of open channel flow; channel cross section; Chezy's and Manning's equation; hydraulically most efficient cross-section.

PRACTICAL:

Applying Manning Formula, in computation of uniform-normal depth, maximum discharge, flow measurement with float method, cutthroat flume and current meter.

BOOKS RECOMMENDED:

1. Choudhry, H. 2008. Open Channel Hydraulics. Springer.
2. Subramanya, K. 2008. Flow in Open Channels. Tata McGraw Hill.
3. Kay, M. 2008. Practical Hydraulics. Taylor & Francis, Oxford, UK.
4. Ali, I. 2007. Irrigation and Hydraulic Structures Theory, Design and Practice. Allied Book Company, Lahore.
5. Akan, A. O. 2006. Open Channel Hydraulics. Butterworth-Heinemann, Burlington, MA, USA.
6. Micheal, A. M. 2003. Irrigation Theory and Practices. Vikas Publishing House, New Delhi, India.
7. Nicolas G. Adrien, N. G. 2003. Computational Hydraulics and Hydrology: An Illustrated Dictionary. CRC, Boca Raton, FL, USA.
8. Sturn, T. 2001. Open Channel Hydraulics. McGraw Hill, New York.
9. Brater, E. F., H. W. King, J. E. Lindell, and C. Y. Wei. 1996. Handbook of Hydraulics. McGraw-Hill Professional, London.

OBJECTIVE:

To enable students to understand theory and practice of surveying and leveling and to develop skills to use modern survey instruments.

THEORY:

Introduction to surveying: definition; importance, types of survey, surveying instruments; chains, tapes, steel bands, their types and uses. Chain surveying: ranging and chaining of survey lines, field-work and plotting of chain survey, errors in chain surveying, chaining through obstacles. Compass surveying: prismatic compass and surveyor compass, Uses, Bearing, Local Attraction, Fieldwork and Plotting. Plane table surveying: parts and accessories, methods of plane table surveying and topographic mapping, contour map preparation and uses, contour lines, two point and three point problems. Introduction to leveling: definition, benefits, general principles and methods of land leveling, types and uses of levels, precision land leveling, trigonometric leveling, leveling instruments/equipments, temporary and permanent adjustments of levels; computation of areas and volumes, land grading, cut-fill ratio and earthwork calculations, measurement of area, cross-section, elevations, contour lines, mass diagram, planimeter and its uses. Theodolite: types and uses of Theodolites, temporary and permanent adjustments, measurement of horizontal and vertical distances and angles, electronic distance measurement (EDM), total station.

PRACTICAL:

Introduction to measuring instruments and practice on measurement of distances; Chain surveying and tapping; Compass surveying and traversing; Level adjustments by Two-Peg method; Plane tabling by radiations and intersections; Profile and Cross-Sectioning; Theodolite Traversing; Global positioning system (GPS); Use of automatic level/Engineer's level.

BOOKS RECOMMENDED:

1. Kanetkar, T.P. 2006. Surveying and Leveling (Part 1). Pune Vidyarthi Griha Prakashan, India.
2. Ministry of Food, Agriculture & Cooperatives. 1996. On Farm Water Management Field Manual, Vol. 2: Precision Land Leveling, Water Management Wing, Government of Pakistan, Islamabad.
3. Johnson, A. 2004. Plane and Geodetic Surveying. Spon Press, London.
4. Schofield, W., and M. Breach. 2007. Engineering Surveying. Butterworth-Heinemann Burlington, MA, USA.
5. Brinker, A.C. and Taylor, W.C. 2002. Elementary Surveying. International
   Text Book Co. Scranton, Pennsylvania.
6. Ramsay, J. P. Wilson. 2000. Land Surveying. Mcdonald and Evans Ltd. Estover, Plymouth.

OBJECTIVE:

To acquaint the students with principles and processes governing the movement of water through the hydrologic cycle, including atmospheric moisture flow, surface runoff, infiltration, and groundwater flow; and hydrologic statistics, and frequency analysis techniques applied to problems of water management

THEORY:

Introduction: hydrologic cycle and its components, climatic factors and their measurements, Precipitation; types and forms of precipitation and their measurement. Rainfall and runoff estimation, runoff and its components, rainfall-runoff relations, factors affecting runoff, stream flow, interpretation of stream flow data, evaporation and transpiration, evapotranspiration and its estimation using different methods. Hydrologic analysis: Hydrograph and its characteristics, hydrographs for various durations, hydrograph separation, unit hydrograph development and application, unit hydrographs from complex storms, rainfall frequency and duration analysis, flood frequency and duration analysis. Hydrologic Models: definition, classification of models, development, calibration, verification and application of models. Groundwater: Occurrence of ground water, aquifers and classification, storage determination, subsurface flow and hydrographs

PRACTICAL:

Demonstration of weather recording instruments and practice in taking actual data from weather stations including a visit to weather station; Measuring runoff in the field by different techniques; Development of unit hydrograph and its use; Frequency analysis of rainfall data; Measuring infiltration rate in the field.

BOOKS RECOMMENDED

1. Davie, T. 2008. Fundamentals of Hydrology. Routledge, Oxon, UK.
2. Schwartz, F. W. and H. Zhang. 2008. Fundamentals of Ground Water. John Wiley and Sons, New York.
3. Todd, T. K. and L. W. Mays. 2008. Groundwater Hydrology. John Wiley and Sons, New York.
4. Raghunath, H.M. 2006. Hydrology Principles, Analysis and Design. New Age International (P) Ltd.
5. Watson, I. and A. Burnett. 1993. Hydrology: An Environmental Approach. CRC Press, Boca Raton, Florida, USA,
6. Ward, R.C., Robinson, M. 1990. Principles of Hydrology. McGraw Hill Book Co., London.
7. Bouwer, H. 1988. Groundwater Hydrology. McGraw Hills Book Company, London.
8. Kruseman, G. P. 1988. Hydrology and Groundwater Resources of NWFP. WAPDA, Pakistan.
9. Awan, N.M. 1981. Surface Water Hydrology, National Book Foundation, Islamabad.

OBJECTIVE:

To provide the students basic rationale of water quality and practical hand in the sampling of water and the measurement and interpretation of water quality parameters.

THEORY:

Introduction: definition, physical properties of water, uses of water, hydrologic cycle, water quality concern, major agricultural pollutants. Chemical water quality issues: drinking water quality, environmental water quality, agricultural water quality. Microbiological water quality issues: public health microbiology; pathogens in drinking water, recreational waters, water for irrigation. Microbiological interactions with chemical pollutants; eutrophication, toxigenic microbes, microorganisms in water distribution systems. Biotic indicators of water quality. Water quality guidelines, standards and legislation. Sampling strategies and methods: surface and groundwater. Sediment measurement. Effects of land use on water quality. Quality assurance. Data handling and interpretation.

PRACTICAL:

Sampling and preservation; drinking, ground, surface and wastewater. Materials and methods of chemical analysis; probes, titrations, chromatography, spectrophotometry. Microbiological testing; plate counts, membrane filtration, MPN. Biological sampling and analysis

BOOKS RECOMMENDED

1. Rao. S.V. 2007. An Introduction to Water Pollution. Icfai University Press
2. APHA. 2001. Standard Methods for Examination of Water and Wastewater. American Public Health Association, New York.
3. Boyd, C. E. 2000. Water Quality: An Introduction. Springer.
4. Zytner, R.G. 1997. Water Quality Laboratory Manual. SoE.
5. Batram, J. 1996. Water Quality Monitoring. UNEP, Tokyo.
6. Adams, V. D. 1990 Water and Wastewater Examination Manual. Lewis Publisher, Florida.
7. Tchobanoglous, G. and E. D. Schroeder. 1987. Water Quality; Addison Wesley.
8. Tomar, M .1999 Quality Assessment of Water and Wastewater. Lewis Publisher, Florida.

SIXTH SEMESTER

WM-007 **IRRIGATION SYSTEMS** 3 (2-1)

OBJECTIVE:
To provide knowledge and skills in conveyance and distribution of water, design criteria of irrigation system, water distribution structures.

THEORY:
Introduction: definition, components of irrigation system, types of irrigation systems. Concept of Irrigation Development: dependency of farmer on water, incompatible farming system, imbalance of power. Design criteria: physical, water management, social and other criteria. Irrigation water distribution: methods, choice of method, water distribution at secondary and tertiary level. Water distribution structures: types and characteristics, selection of outlets. Headwork and control structures: headwork, control structures, falls, canal escape, cross-drainage work.

PRACTICAL:
Study of irrigation regulating structures; irrigation delivery scheduling at tertiary level and preparation of rotational schedule; field visits to various irrigation schemes; determination of conveyance and seepage losses;

BOOKS RECOMMENDED:

1. Ali, Iqbal. 2000. Irrigation and Hydraulic Structures. Institute of Environmental Engineering & Research. NED University of Engineering and Technology.
2. Meijers, T.K., 1990, Design of Smallholder Irrigation Systems. Wageningen Agricultural University, the Netherlands.
3. Horst, L. 1998. The Dilemmas of Water Distribution. International Irrigation Management Institute., Sri Lanka

WM-008 **HYDROMETERY** 3 (2-1)

OBJECTIVE:
To provide the knowledge and skills of hydraulic measurements and its application in agriculture.

THEORY:
Introduction: definition, importance and scope of hydraulic measurements. Gauges; types, gauging stations; recording systems, accuracy in water level measurements and presentation of results. Telemetry system; measurement of bed levels, position fixing, sounding, data processing. Discharge measurements: units and methods, selection of methods, rating curves. Classification, measurement, transport and sediment yield, instruments and sampling techniques. Flow measuring structures, types function and classification.

PRACTICAL:

Use of different equipment and techniques of discharge measurement, evaluation and data analysis. Preparation of rating curves, field visits of various gauging stations and measuring structures, sediment sampling and measurement.

BOOKS RECOMMENDED:

1. Boiten, W. 2008. Hydrometery: A Comprehensive Introduction to Measurement of Flow in Open Channels. UNESCO-IHE Lecture Notes Series. Taylor & Francis, Oxford, London.
2. Herschy, R. W. 1998. Hydrometry: Principles and Practice. John Wiley & Sons, New York.
3. Bos, M. G.1989. Discharge Measurement Structures. ILRI Publication No. 20, The Netherlands.
4. Government of Pakistan.1986. On-Farm Water Management Field Manual: Flow Measurement (Vol. III). Federal Water Management Cell, Islamabad.
5. Kraatz, D. B. and I. K. Mahajan.1982. Small Hydraulic Structures. FAO Irrigation and Drainage Paper 26, Vol.1 and 2.

WM-009 **IRRIGATION SCHEDULING** 3 (2-1)

OBJECTIVE:

To provide the students a comprehensive introduction in the climatic, crop, soil and environmental aspects that determine the water balance of a cultivated field and in the calculation of the crop water and irrigation water requirement at field

THEORY:

Introduction: evapotranspiration, importance, units of measurement. Agro-hydrologic cycle: definition, agro-hydrologic cycle for major agro-ecological zones. Processing and analysis of weather data: methods on the processing and analysis of weather factors like temperature, precipitation, wind, sunshine, humidity and evaporation. Determination of potential evapotranspiration: estimation using aerodynamics, energy balance and empirical formulas. Crop water requirement: crop-coefficient values, evapo-transpiration, effective rainfall, readily available moisture (RAM), effect of RAM on reference evapo-transpiration. Calculation of Irrigation Requirements: calculating allowable depletion; Soil characteristics, root zones, available capacity and MAD; calculating rate of depletion (net irrigation requirements). Adjusting estimates of net irrigation requirements: Adjusting net irrigation requirements; Salinity and leaching requirements, Effective rainfall, ET during soil drainage, capillary movement from a water table. Gross water requirements: Irrigation efficiency; uniformity, adequacy and timing, estimating efficiency; spray loss, percolation, runoff, leaching fractions; managing salinity, sodicity, specific ion effects; estimating gross irrigation requirements. Irrigation scheduling: definition, methods,

PRACTICAL:

Computation of reference crop evapo-transpiration, crop water requirement, irrigation requirements, leaching requirements and irrigation scheduling. Computer models for irrigation scheduling.

BOOKS RECOMMENDED:

1. Allen, R. G., L. S. Pereira, D Raes, and M. Smith. 1998. Crop Evapotranspiration - Guidelines for Computing Crop Water Requirements. FAO Irrigation and Drainage Paper 56. FAO, Rome, Italy
2. FAO. 1992. Crop Water Requirements. FAO Irrigation and Drainage Paper No. 24, Rome.
3. Nielsen, D. R. 1990. Irrigation of Agricultural Crops. Agronomy No. 30. Publ. ASA, CSSA, SSSA.
4. Cuenca, R. H. 1989. Irrigation System Design - An Engineering Approach. Prentice Hall, Englewood Cliffs, NJ.
5. Awan. N.M. 1986. Surface Water Hydrology. National Book Foundation, Islamabad.
6. Teare, I.D., and M.M. Peet. 1983. Crop Water Relations. John Wiley and Sons. New York, USA.

WM-010 **WATERSHED MANAGEMENT** 3 (2-1)

OBJECTIVE:

To provide an understanding of the physical, chemical, biological, and ecological interactions that occur within watershed basins and the way and extent these affect the quantity and quality of water.

THEORY:

Introduction: Importance and role of watershed management; issues and constraints in watershed management; socio-technical approaches for development; sustainable integrated watershed management. Concepts and approaches to participatory watershed management: Overview of recent approaches; new developments in socio-economic concepts; Small and large watershed development and biodiversity, conflict resolution. Appropriate technology and practices: Rehabilitation of degraded land; agroforestry systems and practices; Bio-engineering practices for soil and water conservation, land slide control in upland watersheds; natural resource management; Bio-technology of natural resource management, soil and water conservation. Water harvesting Practices: Micro-catchment development in local, regional and global; catchment area ratio and grid spacing; land development techniques. Reducing runoff losses; Agronomic practices; land surface modification, contour bunding; contour trenches; hillside conduit system, reducing evaporation losses (Mulching), reducing losses from reservoirs, forcing deep water penetration, reducing deep percolation Losses, chemical treatment, anti-transpirants

PRACTICAL:

Field study trips to watersheds; study on watershed management; determination of sediment load

BOOKS RECOMMENDED:

1. Gregersen, H., P. Ffolliott, and K. Brookes. 2008. Integrated Watershed Management: Connecting People to their Land and Water. Cabi Publishing.
2. Lal, S. 2004. Watershed Development, Management and Technology. Mangal Deep Publications, India.
3. Bhatta, B.R., Chalise, S.R., Myint,A.K., and Sharma, P.N. 1999. Recent Concepts, Knowledge, Practices & New skills in PIWM. Dept. of Soil Conservation and Watershed Management, Nepal.
4. Lal, R. 1999. Integrated Watershed Management in the Global Ecosystem. CRC Press, Boca Raton, Florida, USA.
5. Dobson C. and G. G. Beck. 1999. Watersheds: A Practical Handbook for Healthy Water. Firefly Books, New York.
6. Heathcote I W, Integrated Watershed Management, 1998, John Wiley & Sons. Inc.
7. Reimold R J, 1998, Watershed Management: Practice, Policies and Coordination. McGraw-Hill Companies.
8. OFWM. 1996. Water Harvesting and Spate Irrigation. OFWM Manual: Vol. X, Islamabad, Pakistan
9. Arnold P., and C. Adrin. 1986. Rainwater Harvesting. International Technology Publications, London

WM-011 **AGRICULTURAL METEOROLOGY** **3 (2-1)**

OBJECTIVE:

To provide know-how regarding Earth's climate and weather systems, processes and the relationships between the atmosphere and climate and its role in agriculture.

THEORY:

Introduction; scope, importance, composition of atmosphere. Weather and climate, measurement of weather parameters. Micro-meso-macro-phyto climates, electromagnetic spectrum, nature and properties of solar radiation, transfer of heat, seasons, radiation and heat balance, vertical structure of atmosphere. Factors responsible for spatial and temporal variations in surface air temperature, diurnal and monthly variation of temperature, vegetation and air temperature. Atmospheric pressure and its variation with height, global distribution of pressure and wind, atmospheric humidity, saturation and actual vapor pressure, relative humidity and dew point temperature, cloud formation and classification, types and forms of precipitation, rainfall over Pakistan. Monsoon. Agricultural seasons, weather and crops, crop weather relationships, climate types and vegetation, temperature and vegetation, influence of altitude on crop distribution, influence of weather on crops. Weather forecasting in agriculture, weather and fertilizer application, weather

service to farmers, crop weather diagrams and calendars, role of weather on insect pest and diseases, weather and climate related natural disasters, risk and management, climate change and global warming, weather modification, remote sensing.

PRACTICAL:

Visit of meteorological observatory, selection of site and layout of agro meteorological stations. Installation and measurement of meteorological instruments. Identification and measurement of clouds. Measurement of rainfall and open pan evaporation. Automatic weather station and recording of weather data, processing and presentation of data, weather charts, preparation of crop weather calendars

BOOKS RECOMMENDED:

1. Stigter, K. (Ed.). 2009. Applied Agrometeorology. Springer.
2. Prasad Rao, G. S. L. H. V. 2008. Agricultural Meteorology, Prentice-Hall of India Pvt. Ltd., New Delhi.
3. WMO. 2006. Commission for Agricultural Meteorology - Fourteenth session - Abridged Final Report with Resolutions and Recommendations. WMO Publication, Geneva, Switzerland.
4. Harpal S., Ph.D. Mavi, Graeme J. Tupper**.** 2004. Agrometeorology: Principles and Applications of Climate Studies in Agriculture. CRC Press, Boca Raton, Florida, USA.
5. Varshneya, M. C. and Balakrishna Pillai, B. 2003.Text Book of Agricultural Meteorology. Indian Council of Agricultural Research, New Dehli.
6. Radha Krishna Murthy, V. 2002. Basic Principles of Agricultural Meteorology. BS Publications, Hyderabad, India.
7. Venketaraman, S. and Krishnan, A. 1992. Crops and Weather. ICAR, New Delhi.
8. Mavi, H. S. 1986. Introduction of Agrometeorolgy. Oxford & IBH Publishing Co. New Delhi.
9. Sachati, A. K. 1985. Agricultural Meteorology: Instruction-cum-Practical Manual. NCERT, New Delhi.

SEVENTH SEMESTER

WW-012 **SURFACE IRRIGATION** **3 (2-1)**

OBJECTIVE:
To provide an understanding of the basic surface irrigation methods, irrigation delivery systems and schedules and evaluation of irrigation methods.

THEORY:
Introduction: basic concepts; advance, depletion, cutoff and recession phases; surface, subsurface and pressurized irrigation methods; irrigation efficiency and distribution uniformity, factors affecting efficiency and uniformity. Modes of surface irrigation: basin; border; furrow; flooding and surge. Irrigation delivery systems and schedules: crop based, continuous, and rotational water supply schedules; crop water requirement and irrigation scheduling, constant and variable water supply; evaluation of irrigation methods; uniformity and reliability.

PRACTICAL:
Study and demonstration of different surface irrigation methods. Determination of irrigation efficiencies; evaluation of different phases of irrigation methods

BOOKS RECOMMENDED:

1. Laycock, A. and A. Laycock. 2007. Irrigation Systems: Design, Planning and Construction. Cab Publishing.
2. Cech, T. V. 2005. Principles of Water Resources: History, Development, Management, and Policy. John Wiley & Sons, Hoboken
3. Kahlown, M.A. and W. D. Kemper. 2004. Reducing Conveyance Losses from Water Channels. PCRWR, Ministry of Science and Technology, Government of Pakistan
4. Dilip, K.M.2004. Irrigation Water Management Principles and Practices. Prentice Hall of India, New Delhi
5. Michael, A.M. 2003. Irrigation, Theory and Practice. Vikas Publishing House, New Delhi, India.
6. Ahmad, C. R. 2001. Irrigation and Drainage Practices. University of Agriculture, Faisalabad.
7. James, L. G. 1993. Principles of Farm Irrigation System Design. Krieger Publishing Company, Florida, USA.
8. Walker, W.R. and G. V. Skogerboe. 1987. Surface Irrigation: Theory and Practice. Prentice Hall, New Jersey.
9. Jensen, M. E. 1982. Design and Operation of Farm Irrigation System. ASAE Monograph No.3, American Society of Agricultural Engineer, USA.

WM-013 **PARTICIPATORY WATER MANAGEMENT** 3 (2-1)

OBJECTIVE:

To provide students with basic knowledge about the rates of water users in irrigation management.

THEORY:

Introduction: Users' participation in development and management of irrigation: strategies for approaching farmers; integrated rural development, target group development; target groups in irrigation; practical methods to communicate with farmers; farmers socio-economic context and irrigation development: the farming system; farmers' organizations; external relations of farmers for arranging inputs and outputs; the link of these aspects with irrigation design; construction and operation. Water Users' Associations; Water Users' Association Act. Water agreements/accords: local; regional and global; legislation about water and water vision of Pakistan. Mass awareness; key water issues in Pakistan; electronic and print media; consultations; holding events; demonstrations of improved techniques and practices.

BOOKS RECOMMENDED:

1. Ahmad, Nisar. 2008. Participatory Irrigation Management. Higher Education Commission, Islamabad.
2. Kahlown, M. A. and A. Majeed. 2004. Pakistan Water Resources: Development and Management. PCRWR, Government of Pakistan.
3. Khan, M. I., B. A. Tahir, S. Amir and N. Akhtar. 2004. Towards Participatory Management, Allama Iqbal Open University.
4. Shepherd, A. 1998. Sustainable Rural Development, St. Martin Press, Inc.
5. Burkey, S. 1993. People First: A Guide to Self-reliant Participatory Rural Development. Zed Books, London.
6. Uphoff, N. 1992. Learning from Gal Oya: Possibilities for Participatory Development and Post-Newtonian Social Science. Cornel University Press, Ithaca.
7. Nobe, K. C. and R.K. Sampth. 1986. Irrigation Management in Developing Countries; Current Issues and Approaches, Studies in Water Policy and Management No. 8, West View Press, USA.

WM-014 **WATER SUPPLY AND SANITATION** 3 (2-1)

OBJECTIVE:

To provide the students with basic knowledge of water supply and sanitation

THEORY:

Introduction: Overview of water supply and sanitation in Pakistan; Health aspects of water supply and sanitation; water quality criteria. Water

supply: sources of water, choices of water sources (spring, wells etc) and their protection; forecasting population; consumption for various purposes, factors effecting consumption; economics of community water supply. Water treatment and distribution: sedimentation tank; coagulation; flocculation, usual coagulants, mixing devices, filtration, filter sand, classification of filters, disinfections, and chlorination. Sanitation and wastewater treatment: purpose of sanitation, site for sewage treatment work; water borne diseases and their control; health and water chemistry; planning and design of low cost sanitation; composting and biogas, sanitation and irrigation; agriculture and aqua cultural reuse.

PRACTICAL:

Determination of physical, inorganic and organic characteristics of water, waste water and sewage. Determination of Bacteriological characteristics (Coliform count) of water and waste water. Determination of Coagulation (Floc test) in water. Visit to sewerage treatment plant.

BOOKS RECOMMENDED:

1. Steel, W. Ernest. 1999. Water Supply and Sewerage. McGraw Hill Book Co. USA.
2. World Bank. 1999. Urban Water Supply and Sanitation (South Asian Rural Development Series). World Bank Publications.
3. DFID. 1998. Guidance Manual on Water Supply and Sanitation Programmes. Dept. for International Development (DFID), UK
4. Cairncross, S. and R.G. Feachem. 1993. Environmental Health Engineering in the Tropics. John Wiley and Sons, Inc., New York.

WM-015 **WATER WELLS AND PUMPS** 3 (2-1)

OBJECTIVE:

To learn the essential theory of ground water structures, wells/tube wells, and pumps, with particular emphasis on problem solving and meeting the requirements of developing nations.

THEORY:

Introduction: Functions of pumps and tubewells, importance of pumps and tubewells in irrigation and drainage, groundwater exploitation by tubewells. Description of Tubewells: Components of a tubewell, factors affecting selection of site, well drilling methods; cable tool method, direct rotary method, inverse rotary method and their respective merits and demerits, depth of well, well casing, well screen, filter pack. Well development methods, well losses, well efficiency, well logs, gravel packing and well maintenance. Skimming and scavenger wells. Pumps: components and classification; centrifugal, jet, positive displacement, turbine pumps, submersible pumps, propeller and mixed flow pumps and air lift pumps- Types of impellers. Terminology in pumping systems- specific speed, priming, pumping energy, total dynamic head, pump problems and their remedies. Power requirement of pump. Irrigation System Head and Power Requirements: Suction lift, well draw down, friction head loss, operating

head-seasonal-variation in system head curve, pump selection, prime mover electric, diesel and their selection, feasibility of prime mover selection.

PRACTICAL:

Study of components and operational characteristics of various pumps. Use of characteristic curves of different pumps. Determination of pump efficiency. Study of various components of tubewell. Discharge measurement of a tubewell

BOOKS RECOMMENDED:

1. Michael, A. M., S.D. Khepar, and S.K. Sondhi. 2008. Water Wells and Pumps. McGraw-Hill
2. Georg Houben, G., and C. Treskatis. 2007. Water Well Rehabilitation and Reconstruction. McGraw-Hill Professional
3. Misstear, B., D. Banks, and L. Clark. 2006. Water Wells and Boreholes. Wiley
4. Ahmad, N., 1995. Groundwater Resources of Pakistan, Shahzad Nazir Publisher, Gulberg,III, Lahore.
5. Ahmad, N., 1995. Tubewell Theory and Practices, Shahzad Nazir Publisher, Gulberg,III, Lahore.
6. Johnson. 1988. Ground Water and Wells. Minnesota, USA.

EIGHT SEMESTER

WM-016 **PRESSURIZED IRRIGATION** 3 (2-1)

OBJECTIVE:

To equip the students with technical design and evaluation of pressurized irrigation systems, including system layout, pipe sizing, water applicator selection, pumping system hydraulics, water filtration requirements, and water application uniformity and efficiency.

THEORY:

Introduction; definition, scope, types, advantages and disadvantages. Sprinkler Irrigation: components, types. Principles of sprinkle system design, layout and selection. Sprinkle system evaluation; pressure requirements for set sprinkler systems. Trickle Irrigation: components and methods, Design of trickle irrigation. System layout, selection of emission devices. Control of clogging; filtration, settling basin, media filter, screen filter, chemical treatment. Evaluation of trickle irrigation systems. Low head pipelines: buried pipe distribution systems and selection for surface irrigation, system planning and design, design consideration for component structures, post-construction issues, cost analysis; upgrading and development.

PRACTICAL:

Design of a small sprinkle irrigation system, selection of sprinklers, and evaluation of sprinkler system. Design of a small drip irrigation system, selection of proper emitter, and evaluation of drip irrigation system. Visit to a sprinkler and trickle irrigation project site.

BOOKS RECOMMENDED:

1. Phocaides, A. 2007. Handbook on Pressurized Irrigation Techniques. Food and Agriculture Organization of the United Nations, Rome.
2. Kessler and Sunset Books Staff. 2006. Sprinklers and Drip Systems. Oxmoor House, Inc., Des Moines, Iowa.
3. Keller, J. 2001. Sprinkle and Trickle Irrigation. Blackburn Press, New Jersey.
4. Bliesner, R. D. and Keller, J. 2001. Sprinkle and Trickle Irrigation. Van Nostrand Reinhold.
5. Ahmed, S., M. Yasin, M. Aslam, A,G. Mangrio, M.M. Ahmed, R. Majeed, A. Rehan and T. Mustafa, 2001. A Handbook on Pressurized Irrigation Systems and Innovative Adaptations, WRRI, NARC, Islamabad.
6. Lamaddalena, N. and J. A. Sagardoy. 2000. Performance Analysis of On-demand Pressurized Irrigation Systems. Food and Agriculture Organization of the United Nations, Rome.
7. NARC. Handbook of Sprinkle Irrigation Systems. 1992. Water Resources Research Institute, National Agricultural Research Council (NARC), Islamabad.

8. Bentum, Robert van and Ian K. Smout.1994. Buried Pipelines for surface irrigation. The Water, Engineering and Development Center. Loughborough University of Technology, UK.
9. Ahmed, S., P.M. Moshabbir. 1992. Handbook of Sprinkler Irrigation Systems; Part-I: Sprinkler Irrigation Technology, Hydraulics and Design of Raingun Systems, Water Resources Research Institute, National Agricultural Research Council (NARC), Islamabad.
10. Ahmed, S. and P.M. Moshabbir. 1990. Methodology Handbook on Trickle Irrigation-Design, Installation, Operation, Field Evaluation and Adoption in Pakistan, WRRI, PARC, Islamabad.
11. BC Ministry of Agriculture. 1987. B.C. Trickle Irrigation Manual. Irrigation Industry Association of BC, Canada.

WM-017 **AGRICULTURAL DRAINAGE** 3 (2-1)

OBJECTIVE:

To equip the students with detailed knowledge of waterlogging and salinity problems, drainage investigation and design of surface, sub-surface and vertical drainage systems.

THEORY:

Introduction: the need for drainage; purpose of drainage; benefits of drainage; effect of poor drainage on soil and plant; drainage problems in Pakistan; sources of excess water; relationship of irrigation and drainage. Rainfall and its relationship to drainage: the mean rainfall over a basin or watershed; frequency of rainfall; characteristics of storm; time of concentration; the time of overland flow; different formulas for estimating runoff. Flow of water through soil: occurrence of ground water; saturated and unsaturated flow; flow of water through soil (Darcy's Law); measurement of hydraulic head; capillary flow above the water table; critical water table depth measurement of hydraulic conductivity; soil salinity control; leaching requirements. Surface drainage systems: open drain design; maintenance of open drains. Subsurface drainage system: interceptor drain; relief drains; mole drains; material for subsurface drainage system; design criteria for subsurface drainage system; drainage coefficients; drain spacing formula; Hooghoudt's formula for steady state; determination of design depth and pipe diameter; lay-out and patterns; the pipe; and the envelope materials. Vertical drainage system: factors affecting the feasibility of drainage wells; design of drainage well systems; problems associated with vertical drainage; causes of failure of vertical drainage in Pakistan

PRACTICAL:

Measurement of ground water table; auger hole method; constant and inverted auger hole method; field determination of hydraulic conductivity; calculating drain spacing; field trip to subsurface drainage scheme.

BOOKS RECOMMENDED:

1. Smedema, L. K. W. F. Vlotman, D. W. Rycroft. 2004. Modern Land Drainage: Planning, Design and Management of Agricultural Drainage Systems. Taylor & Francis
2. Micheal, A. M. and A. K. Bhattacharya. 2003. Land Drainage: Principles Methods and Application. Konark Publishers Pvt Ltd, India.
3. Siddiqui, I. H. 2003. Irrigation and Drainage Engineering. Royal Book Company, Karachi.
4. Ritzema, H. P. 1994. Drainage Principles and Applications. ILRI Publication 16. International Institute for Land Reclamation and Improvement, Wageningen, Netherlands.

WM-018 **IRRIGATION SCHEME DEVELOPMENT** 3 (2-1)

OBJECTIVE:

It focuses on the technical, framer's participation, organization sociology, project planning and economics issues related to management of irrigation schemes. These concepts are applied by the students to a real Pakistani case study in the form of a new tube well irrigation scheme.

THEORY:

Introduction to the scheme development process; Development of criteria for the selection of a scheme area on the basis of geophysical, irrigation technical and social criteria; The project cycle and strategies for farmer's participation. Scheme design; pump selection and capacity calculation; design of cropping pattern, cost-benefit analysis of lining of canals, layout and canal design, budget for the whole scheme; Scheme management: calculation of the required irrigation intervals, plans and rules for the operation and management of the scheme; Economic evaluation in which the cost-benefit ratio for the whole irrigation scheme is calculated form a farmer's perspective

PRACTICAL:

Selection of a pump for the scheme; compute the capacity of the pump; analyze the involvement and participation of different stakeholders in the development process of the irrigation scheme; design a cropping pattern and compute the irrigation requirements of the scheme; layout of watercourses on the map of the scheme; longitudinal profile and design of watercourse for the scheme; preparation of the scheme budget; compute the irrigation intervals of different crops and design a water distribution plan; cost-benefit analysis of the scheme.

BOOKS RECOMMENDED:

1. Djibril, A. W. and G. Diemer. 2005. Making a Large Irrigation Scheme Work: A Case Study from Mali. World Bank Publications.
2. FAO. 2004. Nega-Nega Irrigation Scheme Development. FAO, Rome.
3. Hussain, M. 2004. Impact of Small Irrigation Scheme on Poverty Alleviation in Marginal Areas of Punjab, Pakistan. M. Sc. (Hons) Thesis. University of Agriculture, Faisalabad.

4. Agriculture New Zealand Ltd. 2001. Irrigation Scheme Development. MAF Information Bureaue, Wallington.
5. FAO. 2001. Socio-economic Impact of Smallholder Irrigation Scheme Development in Zimbabwe: Case Study of Ten Irrigation Schemes. FAO, Rome.
6. Khan, M. Z. and M. de Bont. 1996. Project Studies Water Management. Lecture Notes. Department of Water Management, NWFP Agricultural University, Peshawar.
7. Doorenbos, J. and W. O. Pruitt. 1992. Guidelines for Predicting Crop Water Requirements. Irrigation and Drainage Paper 24. FAO, Rome, Italy.
8. Uphoff, N. 1986. Improving International Irrigation Management with Farmer Participation: Getting the Process Right Studies in Water Policy and Management, No. II, Westview Press. USA.
9. Doorenbos, J., and A. H. Kassam. 1986. Yield Response to Water. Irrigation and Drainage Paper 33. FAO, Rome, Italy

WM-019 **GIS AND REMOTE SENSING** 3 (2-1)

OBJECTIVE:

To equip the students with fundamental concepts of GIS/RS and its application

THEORY:

Concepts of GIS: what is GIS, components of GIS, GIS data models, spatial data model, basic map concepts and map reference system, projection system. Spatial Data Acquisition and Management: Data acquisition techniques, accuracy and precision, concepts on GIS Database management systems. Spatial Analysis: spatial analysis concepts, functions, maintenance and analysis of spatial data, maintenance and analysis of attribute data, retrieval, classification and measurement, overlay operations, vector overlay, Raster overlay, Buffer zones. Global Positioning System: brief history, components of GPS, how GPS works, using GPS, GPS errors, absolute positioning, differential positioning. Cartography: maps, types of maps, scale, map reading, uses of maps. Concepts of Remote Sensing: introduction, how remote sensing works, major components of remote sensing, electromagnetic radiation, electromagnetic spectrum, physical basis of remote sensing, an idea remote sensing system, Remote Sensing Platforms and Sensors: types of platforms, orbit of satellite, types of satellite orbits, Remote Sensing satellites, functions remote sensing satellites, sensors, characteristics of optical sensors, multi-spectral scanners, across-track scanning, along-track scanning. Earth Resource Remote Sensing Satellite: LANDSAT, IKONOS, QuickBird, SPOT-5, ASTER and others, Remotely Sensed Data Characteristics: spectral resolution, radiometric resolution, spatial resolution, temporal resolution, spectral signatures, interpretation elements. Digital Image Processing: image restoration and rectification, image enhancement, image classification. Aerial Photography: history,

vantage points, aerial cameras, aerial photography films, planning aerial photography missions. Report designing and generation

PRACTICAL:

Introduction to ArcGIS; displaying spatial data; classifying features and rasters; labeling features; digital elevation model (DEM); advanced spatial analysis; exploring ERDAS IMAGINE; image classification.

BOOKS RECOMMENDED:

1. Liu, J. G., and P. Mason. 2009. Essential Image Processing and GIS for Remote Sensing. John Wiley & Sons Inc., New York, USA.
2. Weng, Q. 2009. Remote Sensing and GIS Integration: Theories, Methods, and Applications: Theory, Methods, and Applications. McGraw-Hill Professional, Dubuque, IA, USA.
3. Chang, Kang-Tsung. 2006. Introduction to Geographic Information Systems. McGraw-Hill Higher Education, Columbus, Ohio, USA
4. Shamsi, U.M.. 2005. GIS Applications for Water, Wastewater, and Stormwater Systems
   CRC, Boca Raton, FL, USA
5. Jensen. J. R. 2004. Introductory Digital Image Processing. Prentice Hall, Inc., New Jersey, USA.
6. Bernhardsen, T., A. Viak and A. Norway. 2002. Geographic Information System: An Introduction. John Wiley & Sons Inc., New York, USA
7. Maidment, D. R. 2002. Arc Hydro: GIS for Water Resources. ESRI, Inc., USA.
8. Dijk, A. van, M. G. Bos. 2001. GIS and Remote Sensing Techniques in Land and Water Management. Springer, USA.
9. ICIMOD. 2001. Application of GIS and RS in Planning for Mountain Agriculture and Land Use Management. International Centre for Integrated Mountain Development (ICIMOD), Nepal
10. Rees, W. G. 2001. Physical Principles of Remote Sensing (Topics in Remote Sensing)
    Cambridge University Press, UK.
11. Lyon, John G. 2001. Wetland Landscape Characterization: GIS, Remote Sensing and Image Analysis. CRC, Boca Raton, FL, USA.
12. Jensen, J. R. 2000. Remote Sensing of the Environment. Prentice Hall, New Jersey, USA.

WM-020 **PROJECT/INTERNSHIP** 3 (2-1)

OBJECTIVE:

All the universities/faculties/colleges may adopt project studies/internship programs according to their local environment/circumstances and may use their own procedure for evaluation. On completion of internship each student is required to write a formal report on his/her work and will present the report in seminar. The seminar / presentation delivered for internship will be mandatory but not be considered extra credit.

Curriculum for MS/MSc (Hons)/Ph.D in Water Management
General Objectives of the Programme

The MS (Hons)/Ph.D. programme focuses on the integrated management of hydrological features such as catchments, river basins and deltas. Integrated water management involves a process of participatory planning, decision making and implementation with the aim of achieving sustainable use of land and water resource systems. There is competition for water – regarding both its quantity and quality – between various uses and users. Water management has become a political issue that must be adapted to the needs of various stakeholders at all policy levels. In order to act within such a context, graduates must be capable of analyzing various forms of water use by various stakeholders; they must also be able to understand the strategies and viewpoints of decision makers and to assess alternative water management systems.

Learning Outcomes of MS/M.Sc (Hons)/Ph.D Programme

After completing this specialization, graduates will:

- Have understanding of the physical water system and be able to predict and describe the impacts that human activities can have on the water and environmental resources
- Be able to explain principles, concepts and instruments of water resources and common and desired institutional and management arrangements
- Be able to model processes of water allocation and use at different scales, and interpret model outcomes in order to gain an understanding of problems, trends, causes and effects
- Be able to describe socio-economic concepts that are relevant for water resources planning and management

Scheme of Studies
for MS/M.Sc (Hons)/Ph.D Programme

Course No.	Course Title	Credit Hrs
WM-701	Optimal Use of Water	3 (2-1)
WM-702	High Efficiency Irrigation Systems	4 (3-1)
WM-703	Water Harvesting	3 (2-1)
WM-704	Water Resources Planning and Management	3 (2-1)
WM-705	Irrigation Management	4 (3-1)
WM-706	Drainage and Salinity Management	3 (2-1)
WM-707	Environmental Impact Assessment	3 (2-1)
WM-708	Applied Hydrology	4 (3-1)
WM-709	Water Quality Management	3 (2-1)
WM-710	Soil Erosion and Sediment Transport	3 (2-1)
WM-711	Groundwater Management	3 (2-1)
WM-712	Reservoirs Operations and Management	3 (2-1)
WM-713	Remote Sensing and GIS Applications	4 (3-1)
WM-714	Water Resources and Sustainable Development	3 (2-1)
WM-715	Climate Change and Water Resources	3 (2-1)
WM-716	Wetland Conservation and Management	3 (2-1)
WM-717	Special Topics in Water Management	3 (3-0)
WM-793	Special Problem (M.Sc.)	2 (0-2)
WM-794	Seminar-I (M.Sc.)	1 (1-0)
WM-795	Thesis (M.Sc.)	6 (0-6)
WM-796	Special Problem (Ph.D.)	2 (0-2)
WM-797	Seminar-II (Ph.D.)	1 (1-0)
WM-798	Defense Seminar-III (Ph.D.)	1 (1-0)
WM-799	Dissertation	12 (0-12)

Details of Courses for MS/M.Sc (Hons)/Ph.D Programme in Water Management

WM-701 **OPTIMAL USE OF WATER** 3 (2-1)

OBJECTIVE:

To equip the students with detailed knowledge of optimization principles and practices at the farm level in order to get maximum yield.

THEORY:

The relations between water use and crop yield: crop water use, concept of relative yield and relative evapotranspiration, FAO method and its limitations, difference between seasonal ET deficit and ET deficit within a growth cycle. Elementary optimization principles and practices: choice of crop and variety, comparison of late vs. early varieties, adapting cropped area to water application (concept of full and deficit irrigation), distributing water deficit between crops in dependence of the sensitivity to seasonal and periodical water stress. Different sowing/planting dates and staggering: shifting of crop water requirements and irrigation requirements in time and quantity, staggering sowing/planting: attenuating crop water requirements and irrigation requirements, effects of staggering. The soil moisture reservoir; irrigation scheduling and deficit irrigation: soil properties that can effect crop water requirements, different irrigation scheduling options (optimal vs. practical irrigation), adequacy of irrigation scheduling options, pre-irrigation, carry-over of soil moisture to the next crop, improving irrigation scheduling by water exchange. Optimization of cropping pattern in relation to the availability of land and water resources: how to optimize the cropping pattern of one example farm; Optimization of cropping pattern taking in account farming goals, resources and constraints: effect of farmers goals (subsistence vs. generating cash income), resources (land, labour, water etc.) on the farm-level decisions; how to avoid or minimize risks.

PRACTICAL:

This course makes exhaustive use of computer programme CROPWAT. Practical will focus on determination of potential evapotranspiration (ETo), crop water requirements and irrigation requirements. Different irrigation scheduling and scheme water supply options of CROPWAT will also be practiced. On the basis of climatological, soil, socio-economic data of a certain area, the students will calculate and weigh out the optimal use of water the selected area.

BOOKS RECOMMENDED:

1. Hanson, B. 1999. Scheduling Irrigations: When and how much water to apply? University of California Irrigation Program, USA
2. Allen, R. G., L. S. Pereira, D Raes, and M. Smith. 1998. Crop Evapotranspiration - Guidelines for Computing Crop Water Requirements. FAO Irrigation and Drainage Paper 56. FAO, Rome, Italy

3. Dries, A. V. D. 1994. Lecture Notes: Optimal Use of Water. Department of Irrigation and Soil and Water Conservation, Wageningen Agricultural University, The Netherlands.
4. Doorenbos, J. and W. O. Pruitt. 1992. Guidelines for Predicting Crop Water Requirements. Irrigation and Drainage Paper 24. FAO, Rome, Italy.
5. Rosher, K. 1991. Irrigation Delivery Scheduling. WAMA Project Paper No. WAMA/AUP-90/l1. NWFP Agricultural University, Peshawar.
6. Doorenbos, J., and A. H. Kassam. 1986. Yield Response to Water. Irrigation and Drainage Paper 33. FAO, Rome, Italy

WM-702 HIGH EFFICIENCY IRRIGATION SYSTEMS 4 (3-1)

OBJECTIVE:

This course will educate the students about various types of high efficiency irrigation systems, how to design and evaluate the system.

THEORY:

Selection of systems for orchards and row corps. Irrigation efficiency of the system as compared to the existing irrigation system. Warious parameters used for design of sprinkler/drip irrigation systems. Use of sprinkler units, sprinkler guns, dripper/emitters in the system. Design of sprinkler/drip irrigation systems for the small and large farms. Pre and post installation techniques for sustainability of the system. Fertigation. Buried pipe distribution systems for surface irrigation; distribution system selection; system planning and design; design consideration for component structures; Post-construction Issues; cost analysis; upgrading and development. Qualities of pipes used in the systems. Bill of quantity (BOQ). Selection of pumps. Design and construction of water tank. Operation, maintenance and evaluation of the systems.

PRACTICAL:

Design of sprinkler/drip irrigation systems. Evaluation of the systems. Field visit

BOOKS RECOMMENDED:

1. Kessler and Sunset Books Staff. 2006. Sprinklers and Drip Systems. Oxmoor House, Inc., Des Moines, Iowa.
2. Keller, J. 2001. Sprinkle and Trickle Irrigation. Blackburn Press, New Jersey.
3. Ahmed, S., M. Yasin, M. Aslam, A,G. Mangrio, M.M. Ahmed, R. Majeed, A. Rehan and T. Mustafa, 2001. A Handbook on Pressurized Irrigation Systems and Innovative Adaptations, WRRI, NARC, Islamabad
4. Ahmed, S., P.M. Moshabbir. 1992. Handbook of Sprinkler Irrigation Systems; Part-I: Sprinkler Irrigation Technology, Hydraulics and Design of Raingun Systems, WRRI, NARC, Islamabad.

5. NARC. Handbook of Sprinkle Irrigation Systems. 1992. Water Resources Research Institute, National Agricultural Research Council, Islamabad.
6. Ahmed, S. and P.M. Moshabbir. 1990. Methodology Handbook on Trickle Irrigation-Design, Installation, Operation, Field Evaluation and Adoption in Pakistan, WRRI, PARC, Islamabad.
7. BC Ministry of Agriculture. 1987. B.C. Trickle Irrigation Manual. Irrigation Industry Association of BC, Canada.
8. Bentum, Robert van and Ian K. Smout.1994. Buried Pipelines for Surface Irrigation. The Water, Engineering and Development Center. Loughborough University of Technology, UK.

WM-703 **WATER HARVESTING** 3 (2-1)

OBJECTIVE:

To provide the students with detailed knowledge of various water harvesting techniques and their importance in rain-fed agriculture

THEORY:

Historical and recent developments; Overview of the main types of water harvesting. Rainfall-Runoff Analysis: Rainfall characteristics, Variability of annual rainfall, Probability analysis, Rainfall-runoff relationship, Determination of runoff coefficients; Assessment of annual or seasonal runoff; Runoff plots, Design model for catchment area: cultivated area ratio. Water Harvesting Techniques: Micro-catchments techniques; Contour bunds, eyebrow terrace, hill-slope micro-catchments, negarim, contour ridges etc. Macro-catchments techniques; hillside conduit, stone dams, liman terraces, cultivated reservoirs, farm ponds shallow wells, karez. Water harvesting; floodwater harvesting within the stream bed (Check dams); floodwater diversion (Sailaba, Rod Kohi etc.), Storage, Underground and above-ground storage. Spate irrigation, structures used in spate irrigation. Roof-top water harvesting. Socio-economic and environmental aspects: socio-economic factors; People's demand, priorities and experiences, people's participation and gender issues, land tenure and water law issues; adaption and adoption; Land suitability and area differences. Environmental factors.

PRACTICAL:

Study of rainfall-runoff relationship, design of different water harvesting structures, field study trips to various locations and collecting technical data.

BOOKS RECOMMENDED:

1. Jana, B. L. 2008. Water Harvesting and Watershed Management. Agrotech Publishing Academy, Udaipur, India
2. Singh. 2008. Rainwater Harvesting: Low Cost Indigenous and Innovative Technologies. Macmillan Publishers India
3. S. Patel, D. L. Shah. 2007. Water Management: Conservation, Harvesting and Artificial Recharge. New Age Publications.

4. Lancaster, B. 2006. Rainwater Harvesting for Dryland and Beyond. Volume 1, 2, and 3. Rainsource Press, Arizona
5. Waterfall, P. H. 2006. Harvesting Rainwater for Landscape Use. Cooperative Extension, College of Agriculture and Life Sciences, University of Arizona, Tuscon, USA.
6. Athavale, R. N. 2003. Water Harvesting and Sustainable Supply in India. Rawat Publications, India.
7. Troeh, F. R., J. A. Hobbs., R. L. Donahue. 2003. Soil & Water Conservation for Productivity and Environmental Protection. Prentice Hall, New York.
8. Govt. of Pakistan. 1996. Water Harvesting and Spate Irrigation. On-Farm Water Management Field Manual, Volume X. Federal Water Management Cell, Ministry of Food, Agriculture & Cooperatives, Govt. of Pakistan.
9. Critchley, W. and K. Siegert. 1991. Water Harvesting. Food and Agriculture Organization of United Nations (FAO), Rome.
10. Reij, C., Mulder, P & Begemanm, L.,1988. Water Harvesting Techniques for Plant Production. World Bank, Washington D.C., USA.
11. Fidelibus, M. W. and D. A. Bainbridge. Microcatchement Water Harvesting for Desert Revegetation. Bulletin # 5. Soil Ecology and Restoration Group, Restoration, United States International University, San Diego, USA.
12. LaBranche, A., H. O. Wack, and D. Crawford, E. Crawford, N. J. Sojka, DVM and Cabell Brand. 2007. Virginia Rainwater Harvesting Manual. The Cabell Brand Center, Virginia, USA.

WM-704 **WATER RESOURCES PLANNING AND MANAGEMENT** 3 (2-1)

OBJECTIVE:

To provide an understanding of surfaced ground water resources, planning and management issues, various treaties and economic affords in the management of water resources.

THEORY:

Present status of surface and groundwater resources; water usage in agriculture, urban and rural sector, and hydropower; water resources development potential; major management and sustainability issues; future challenges and options. Surface water resources development and utilization: History of irrigation; Indus water Treaty (1960); Water Apportionment Accord (1991); surface water resources problems; major rivers of Pakistan; average volume of water received; annual rainfall, seasonal inflow, water quality, sediments in rivers and reservoirs; harnessing of hill torrents; flood protection programme. Groundwater resources development and utilization; necessity, aquifers, quality, recharge, extraction; development potential, mining, water table control, artificial recharge of groundwater. Planning and management issues: institutional objectives and constraints; management and sustainability issues - equity in water distribution, operation, management, cost recovery and water delivery efficiencies. Role of modeling, its advantages and

limitations. Environmental degradation; waterlogging/salinity, secondary salinization, salt balance in the Indus Plain, saline water intrusion, pollution of groundwater. Economics of water resources: economic approaches to the problems of resource use; pollution and sustainability; optimal use of renewable and non-renewable resources; pollution, externalities and public goods; valuation of environmental resources. Simple examples illustrating how engineering and microeconomic analysis are used in water resources infrastructure planning and management.

PRACTICAL:

Student will work on a project dealing with water resources planning and management. These projects will deal with some aspect of a real, complex water resources planning and analysis issue of national interest. The projects typically are interdisciplinary and consider such aspects of water resources planning and management as: economics; hydrology, climatology, hydrogeology; environmental health; computer modeling; land use planning; or regional development;

BOOKS RECOMMENDED:

1. Laycock, A. 2007. Irrigation Systems Design, Planning and Construction. CABI International, Wallingford, UK.
2. Griffin, R. C. 2006. Water Resources Economics: The Analysis of Scarcity, Policies and Projects. MIT Press, USA.
3. Mays, L. W. 2005. Water Resources Engineering. John Wiley & Sons, Inc., USA.
4. Loucks, D. P., E. van Beek, J. R. Stedinger, J. P. M. Dijkman, M. T. Villars, 2005. Water Resources Systems Planning and Management: An Introduction to Methods, Models and Applications. UNESCO, Paris.
5. Sarkar, A. K., K. S. Raju and M. L. Das. 2004. Integrated Water Resources Planning and Management. Jain Brothers, India.
6. Jain, S. and V. P. Singh. 2003. Water Resources System Planning and Management. Elsevier, Kidlington, UK
7. Dzurik, A. A. 2002. Water Resoruces Planning. Rowman & Littlefield Publishers, Inc., Lanham, MD
8. Merrett, S. 1997, An Introduction to the Economics of Water Resources: An International Perspective. UCL Press, London.
9. Grigg, N. S. 1996. Water Management: Principles, Regulations and Cases, McGraw-Hill, New York, USA.
10. Ahmad, N. 1993. Water Resources of Pakistan and Their Utilization. Shahzad Nazir, 61-B/2, Gulberg-3, Lahore, Pakistan.
11. James, L. D., and R. R. Lee. 1971. Economics of Water Resources Planning. McGraw Hill, New York, USA
12. Cech, T. V. Year. Principles of Water Resources: History, Development, Management, and Policy. John Wiley & Sons, Inc., USA.

WM-705 **IRRIGATION MANAGEMENT** 4 (3-1)

OBJECTIVE:

To gain detailed knowledge of water delivery process, flow control systems, role of organization and monitoring and evaluation of irrigation systems performance.

THEORY:

Introduction: definition, importance of irrigation management, management cycle, activities in irrigation management. Objective of irrigation management: main interest groups, arranging objective by means and ends. Water delivery polices: acquisition water, water rights, cropping arrangement, water delivery arrangement. Flow control systems: characteristics of flow control, hydraulic of flow control, flow control concept, management objective and inputs. Organization: purpose and function, organizational structure, resource mobilization, farmers participation, development of water users association. Monitoring and evaluation of irrigation system performance: need, framework, purpose, requirements for monitoring, indicators and performance parameters, evaluation.

PRACTICAL:

Excursion to irrigation schemes and study of water delivery and flow control systems; monitoring and evaluation of irrigation system performance; organizational study of irrigation system.

BOOKS RECOMMENDED:

1. Burton, M. A.2010. Irrigation Management: Principles and Practices. Cabi Publications
2. Darra, B. L. and Raghuvanshi, C. S. 1999. Irrigation Management (Vol. 2). Atlantic, India.
3. Lorenzini, G. C.A. Brebbia. 2006. Sustainable Irrigation Management: Technologies and Polices. WIT Transactions on Ecology and Environment.
4. Joshi, L. K. and R. Hooja. 2000. Participatory Irrigation Management. Rawat Publications, India.
5. Malano, H. M. and P. V. Hofwegan. 1999. Management of Irrigation and Drainage Systems. Balkema, India.
6. Hoffman, G. J., T. A. Howell and K. H. Soloman. 1990. Managing Farm Irrigation Systems. American Society of Agriculture Engineers, USA.

WM-706 **DRAINAGE AND SALINITY MANAGEMENT** 3 (2-1)

OBJECTIVE:

To provide in-depth knowledge of drainage and its role in waterlogging and salinity management.

THEORY:

Effect of drainage and salinity on crop yield, the nature and extent of waterlogging and salinity problems in Pakistan; sources of waterlogging,

relationship between irrigation and drainage, diagnosis of drainage/ salinity and selection of control practices. Plant response to waterlogging and salinity. Salt tolerant crops, response to saline and sodic conditions. Irrigation water quality assessments. Leaching, importance and types, leaching fraction. control of root zone salinity, crops salt tolerance, crop production functions spatial and temporal variability in salinity. Land reclamation; surface, subsurface, vertical, dry and bio drainage. Treatment and disposal of drainage water: Use of saline drainage water for irrigation, drainage water treatment and disposal options, institutional and local constraints, economic incentive and environments quality, conjunctive use of water. Drainage and Salinity Management Options: On farm irrigation and drainage practices, Management of dry land saline seeps, project level waterlogging and salinity management options.

PRACTICAL:

Field sampling and monitoring of soil, water and plants; measurement techniques of waterlogging and salinity; Use of dynamic optimisation models in salinity and drainage management (e.g. HYDRUS-2D/3D).

BOOKS RECOMMENDED:

1. Kadam, U. S., R. T. Thokal, S. D. Gorantwar and A. G. Power. 2008. Agricultural Drainage: Principles and Practices. Westville Publishing House, Delhi, India.
2. Denton, J. B. 2007. Agricultural Drainage: A Retrospective of Forty Years Experiences. BiblioLife , Charleston, SC, USA.
3. Sharma, P. E. 2007. Agricultural Drainage and Water Quality. Daya Publishing House, India
4. Chandra, A. E. and A. E. Madramootoo. 2005. Management of Agricultural Drainage Water Quality. Daya Publishing House, India
5. Hanson, B., S. Grattan and A. Fulton. 2003. Agricultural Salinity and Drainage. Publication #93-01. Department of Land, Air and Water Resources, University of California, Davis
6. Tanji, K. K., and N. C. Kielen. 2002. Agricultural Drainage Water Management in Arid and Semi-arid Areas. Food and Agriculture Organization of the United Nations, Rome, Italy.
7. Skaggs, R. W., and J. V. Schilfgaarde. 1999. Agricultural Drainage. American Society of Agronomy, USA.
8. US Dept. of Interior. 1995. Drainage Manual. Scientific Publishers, Jodhpur, India
9. Ritzema, H.P. 1994. Drainage Principles and Application. ILRI Publication No. 16, Wageningen, The Netherlands.
10. Singh, R. V. 1992. Drainage and Salinity Control. Himanshu Publication, India.
11. Abrol, I. P., J. S. P. Yadv, F. I. Masood. 1988. Salt Affected Soils and their Management. FAO Bulletin 39, Rome, Italy.
12. Smedema, L.K. and F.W., Rycroft. 1983. Land Drainage: Planning and Design of Agricultural Drainage Systems, Batsford (BJ) Ltd., Fitzhardinag Street, London

13. Beltran, J. Martinez. 1978. Drainage and reclamation of salt-affected soils: Bardenas area, Spain. International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands.
14. Luthin, M. 1974. Drainage Engineering, John Wiley and Sons, Inc., New York, USA.
15. FAO. 1973. Irrigation, Drainage and Salinity. Food and Agriculture Organization of the United Nations, Rome.
16. Kovda, V. A., Berg, C. Van den, Hagan, R. M. 1973. Irrigation, Drainage and Salinity. An International Source Book. FAO, UNESCO, Hutchinson.
17. Rao, D. L. N., N. T. Singh, R. K. Gupta, and N. K. Tyagi. Drainage of Salt Affected Soils. Central Soil Salinity Research Institute, Karnal, India.

WM-707 ENVIRONMENTAL IMPACT ASSESSMENT 3 (2-1)

OBJECTIVES:

To learn and understand principles, process, and necessary techniques for assessment, mitigation and monitoring.

THEORY:

Overview of environmental impact assessment. Selection of scientific and socio-economic factors in environmental impact assessment. Environmental impact indicators. Baseline study; air, water, soil, sediment. Identification of quantitative and qualitative environmental evaluation criteria; application of traditional and modern techniques. Approaches for identifying, measuring, predicting, and mitigating environmental impacts. Environmental management plan. Environmental standards and the environmental impact assessment process; methodologies for incorporating environmental impact assessment into management decision-making. Public hearing steps and procedures. Environmental evaluation of policies

PRACTICAL:

Learn to review and critically analyze an environmental impact statement document; case studies of water management projects; post construction evaluation of mitigation measures; participation in public hearing meetings

BOOKS RECOMMENDED:

1. Morris, P. and R. Therivel. 2009. Methods of Environmental Impact Assessment. Routledge, Oxon, UK.
2. Therivel R, J. Glasson and A. Chadwick. 2009 Introduction to Environmental Impact Assessment. Routledge, Taylor & Francis Group, Kentucky, USA.
3. Lawrence, D. P. 2005. Environmental Impact Assessment. John Wiley & Sons, Inc., Hoboken, New Jersey.
4. Lee, N. and C. George. 2000. Environmental Assessment in Developing and Transitional Countries. John Wiley & Sons Ltd, England.

5. Awan, N. M. and M. Latif. 1999. Environmental Assessment of Irrigation and Drainage Projects. Volume 1 & 2.
6. Modak, P. and A. K. Biswas. 1999. Conducting Environmental Impact Assessment for Developing Countries. United Nations University Press, New York.
7. Canter, L. W. 1996. Environmental Impact Assessment. McGraw Hill, Inc., New York.
8. Dougherty, T. C. and A. W. Hall. 1995. Environmental Impact Assessment of Irrigation and Drainage Projects. FAO Irrigation and Drainage Paper 53. FAO, Rome.
9. Glasson, J., R. Therivel, R. Therivel, A. Chadwick, J. Glasson, and A. Chadwick. 2005. Introduction to Environmental Impact Assessment. Routledge, Taylor & Francis Group, Kentucky, USA.

WM-708 **APPLIED HYDROLOGY** 4 (3-1)

OBJECTIVE:

To enable students to gain in-depth knowledge of the principles of hydrology for broader application in water management

THEORY:

Measurement, accuracy and hydrological data evaluation. Rainfall data analysis. Discharge analysis. Hydrograph: concept, component and separation. Factors affecting hydrograph shapes, time base of hydrograph, unit hydrograph, derivation of unit hydrograph using matrix solution, mathematical form of s-curve. Hydrological methods for flood routing. Applications of hydrological techniques. Hydrologic statistics: concepts; probability distribution; moments of distribution; co-variance, correlation and regression; frequency analysis; probability plots and goodness-of-fit tests; stochastic time series analysis; methods of time series analysis.

PRACTICAL:

Determination of total runoff, development of unit hydrograph, frequency analysis of hydrological data; assessment of groundwater withdrawal over time; use of computer models for surface and groundwater flow and contaminant transport. HEC-RAS model.

BOOKS RECOMMENDED:

1. Mays, L. W. 2010. Water Resources Engineering. John Wiley & Sons, Inc., New York.
2. Dingman, S. L. 2008. Physical Hydrology. Waveland Press, Inc., Illinois.
3. Manning, J. C. 1996. Applied Principles of Hydrology. Prentice Hall, New Jersey.
4. Todd, D. K. 1995. Groundwater Hydrology. John Wiley & Sons, New York.
5. Chow,Ven Te., D. R. Maidment, L. W. Mays. 1994. Applied hydrology. McGraw Hill, Columbus, USA.

6. Maidment, D. R. 1993. Handbook of Hydrology. McGraw-Hill, Columbus, USA.
7. Mutreja, K. N. 1992. Applied Hydrology. Tata McGraw-Hill Publishing Company Limited, New Delhi.
8. Maidment, D. R., L. W. Mays and Ven Te Chow. 1988. Applied Hydrology. McGraw Hill, Columbus, USA
9. Awan, N. M. 1981. Surface Water Hydrology. National Book Foundation. Islamabad.
10. Ahmad, N. 1974, Groundwater Resources of Pakistan. Ripon Printing Press, Lahore.

WM-709 **WATER QUALITY MANAGEMENT** 3 (2-1)

OBJECTIVES:

To introduce students to a wide range of water quality issues in the field of water management focusing mainly in the area of irrigation /surface water quality.

THEORY:

Introduction: National and World wide water resources, water quality concerns, quantitative description of stream, irrigation and drainage water quality. Water quality as global issue; trans boundary pollution especially issues related to India and Pakistan. Classes of agricultural pollutants agriculture runoff as non-point pollution source, sediment pollution problems, plant nutrient, fertilizers, nitrogen fertilizers, phosphorus fertilizers, plant nutrient pollution problems, eutrophication. Chemicals usage as pollution problem in agriculture, pesticides, herbicides, insecticides and fungicides. Other pollution problems ;animal waste, industrial effluents, salinity, biological water quality problems. Water quality legislations, assessment of risk in water quality. Water quality standards; drinking, effluent, surface, stream, irrigation, US EPA, European and WHO recommendation .Irrigation Water and soil Pollution: Waste water pollution parameter ; physical, chemical, organic. Water quality effects on plants and crop yield. Waste water reclamation and safe reuse options. Natural and biological treatment techniques for water and waste water. Bioremediation of soil.

PRACTICAL:

Use of sampling equipment for ground water, surface water and sediments sampling; Analyses of water quality for physical, chemical and biological parameters.

BOOKS RECOMMENDED:

1. Dinar, A. and J. Albiac. 2009. The Management of Water Quality and Irrigation Technologies. Earthscan Publications Ltd.
2. ASCE. Comprehensive Trans-boundary Water Quality Management Agreement with Guidelines. 2009. American Society of Civil Engineers (ASCE).
3. Rao. S.V. 2007. An Introduction to Water Pollution. Icfai University Press

4. APHA. 2001. Standard Methods for Examination of Water and Wastewater. American Public Health Association, New York.
5. Boyd, C. E. 2000. Water Quality: An Introduction. Springer.
6. Gray, N.F. 1999. Water Technology – An Introduction for Scientists and Engineers. John Wiley & Sons Inc. New York.
7. Tomar, M .1999 Quality Assessment of Water and Wastewater. Lewis Publisher, Florida.
8. Perry, J., and E. L. Vanderklein.1996. Water Quality: Management of a Natural Resource. Wiley-Blackwell
9. Pearce, G.R. 1998. Agrochemical Pollution Risks Associated with Irrigation in Developing Countries: A Guide. Report OD- 141, HR Wallingford, United Kingdom.
10. Ongley, E.D. 1996. Control of Water Pollution from Agriculture. Food and Agriculture Organization of United Nation, Rome.
11. Batram, J. 1996. Water Quality Monitoring. UNEP, Tokyo.
12. Adams, V. D. 1990 Water and Wastewater Examination Manual. Lewis Publisher, Florida.
13. SCS. 1988. Water Quality Field Guide. Soil Conservation Service. United States Dept. of Agriculture, USA.
14. Tchobanoglous, G. and Schroeder, E.D. 1985. Water Quality: Characteristics, Modeling and Modifications. Prentice Hall, New Jersey

WM-710 SOIL EROSION AND SEDIMENT TRANSPORT 3 (2-1)

OBJECTIVE:

This course aims at increasing insights into the relation between soil erosion processes and sediment transport on the one hand and the possible strategies and techniques that can be applied in order to decrease the intensities of soil erosion and to better conserve soil and water, on the other.

THEORY:

Problems of soil erosion and sediment in Pakistan. Water erosion; causes and control practices, stream channel, revised universal soil loss equation (RUSLE). Contouring, strip cropping, contour bunding, graded bunding, broad based terraces, land leveling and grassed water ways conservation structures, gully control structures, sediment retention structures, retaining walls, field spillway, check dams, flood control structures. Wind erosion; wind erosiveness, types of soil movement, controlling surface wind velocity, assessment of wind erosion losses, conserving soil moisture. Sedimentation; sediment measurements; dynamics of suspended and bed sediment transport in erodible channels; erosion, transportation, and deposition of sediment by flowing water; depth-discharge relations for rivers; bed load and suspended load movement. Comparison of different sediment transport equations, bed load transport, suspended load, total load transport equations. Degradation and conservation of land and water; Land sustainability indicators, limiting factors in plant production affected by erosion, land slides, torrent and stream band erosion and protection. Sedimentation control measures.

PRACTICAL:

Assessment of water erosion, soil erodabality, rainfall erosion; assessment of suspended sediment in canals, design of soil conservation structures, field trip to different water and wind erosion sites.

BOOKS RECOMMENDED:

1. Owens, P. N. and A J Collins. 2006. Soil Erosion and Sediment Redistribution in River Catchments: Measurement, Modeling and Management. Cabi Publishing, Wallingford, UK.
2. Toy, T. J., G. R. Foster. and K. G. Renard, 2002. Soil Erosion: Processes, Prediction, Measurement, and Control. John Wiley & Sons, New York.
3. Schwab, G. O., D. D. Fangmeier, W. J. Elliot, R. K. Frevert, 1993. Soil and Water Conservation Engineering. John Wiley and Sons, New York.
4. Troeh, F. R., J.A Hobbs, and R. L. Donahue. 1980. Soil and Water Conservation for Productivity and Environmental protection. Prentice-Hall, New Jersey.
5. Vanoni, V.A. 1977. Sedimentation Engineering. ASCE Manual and Technical Report No. 54

WM-711 **GROUNDWATER MANAGEMENT** 3 (2-1)

OBJECTIVE:

To equip the students groundwater exploration techniques, well design, groundwater monitoring and conjunctive use of surface and groundwater.

THEORY:

Groundwater exploration: reconnaissance survey, surface investigation methods. Subsurface investigations including test drilling, drilling methods, resistivity logging, radiation logging, temperature logging, velocity measurement and other methods. Well design, construction and development. Deterioration of wells; its causes and remedial measures. Groundwater monitoring: observation network, watertable fluctuation. Selection of sites for the observation network. Installation of observation wells and piezometers. Conjunctive use of surface and groundwater.

PRACTICAL:

Resistivity survey, interpretation of resistivity data, well design, analysis and interpretation of well data.

BOOKS RECOMMENDED:

1. Bisson, R. A. and Jay H. Lehr. 2004. Modern Groundwater Exploration: Discovering New Water Resources in Consolidated Rocks Using Innovative Hydrogeologic Concepts, Exploration, Drilling, Aquifer Testing and Management Methods. Wiley-Interscience
2. Mahajan, G. 1995. Ground Water Survey and Investigation. Ashish Publishing House, New Dehli, India.
3. Chow,Ven.Te., D. R. Maidment, L. W. Mays. 1994. Applied Hydrology. McGraw Hill International Edition, London

4. Mutreja, K. N. 1992. Applied Hydrology. Tata McGraw-Hill Publishing Company Limited, New Delhi, India.

WM-712 RESERVOIR OPERATION AND MANAGEMENT 3 (2-1)

OBJECTIVE:
To acquaint the students with the understanding of reservoir operation and problems related to management of reservoirs.

THEORY:
Introduction: purpose of reservoir operation. Reservoirs classification; storage, flood control, retarding, detention and distribution reservoirs. Hydrological data required for reservoir operation, reservoir operation rules, policies and procedures. Major reservoirs of Pakistan and their operational and management rules. Regulation of flood control, power generation, irrigation reservoirs. Single and multipurpose operation, reservoir operation using system analysis techniques and operational research. Determination of reservoir capacity required for specific yield or demand using mass curve. Demand pattern for various type of reservoirs. Flood routing by graphical inflow; outflow discharge curve method; Trail and error method. Sources of sediment; Factors affecting erosion, silt load estimate for reservoirs; Mechanism of sediment distribution in reservoirs; Prediction of sediment distribution; Estimation of life of a reservoir. Operation and Maintenance of small dams: Maintenance of spillways, outlet pipes, earth embankments and foundation, storage dams, diversion dams, flood detention reservoirs; emergency preparedness plan, periodic examination and evaluation, reservoirs problem, silting seepage control, toxic algae, reservoir safety, marine life.

PRACTICAL:
Reservoir operation using simulation methods with help of historic and simulated inflows, Computer models for reservoir operation.

BOOKS RECOMMENDED:
1. Loucks, Stedinger and Haith. 1999. Water Resources System Planning and analysis. Prentice Hall, New Jersey.
2. Guggino, E., Rossi,Giuseppe, Hendricks,D. 1998. Reservoir Operation. Martinus Nijhoff Publishers, The Hauge.

WM-713 REMOTE SENSING AND GIS APPLICATIONS 4 (3-1)

OBJECTIVE:
To acquaint the students with GIS/RS technologies and their diverse applications in water management through hands on learning.

THEORY:

Review of basic concepts of remote sensing (RS) and Geographical Information Systems (GIS). Field-scale applications of RS and GIS: soil moisture content assessment, crop phenologic stage identification, crop biomass and yield production estimation, crop disease, weed and insect infestation detection and monitoring. Large-scale applications of RS and GIS: farms mapping, cropping system analysis, agro-ecological zoning, retrieval of agrometeorological parameters from satellites. Application of remote sensing and GIS in water management: evapotranspiration, drought and flood assessment and monitoring, water and wind induced soil erosion assessment, water quality mapping and analyses; evaluation of the physical attributes of water resources; groundwater inventory, canal alignment, irrigation performance evaluation

PRACTICAL:

Use of Remote Sensing and GIS software for solving agricultural and water management problems

BOOKS RECOMMENDED:

1. Liu, J. G., and P. Mason. 2009. Essential Image Processing and GIS for Remote Sensing. John Wiley & Sons Inc., New York, USA.
2. Weng, Q. 2009. Remote Sensing and GIS Integration: Theories, Methods, and Applications: Theory, Methods, and Applications. McGraw-Hill Professional, Dubuque, IA, USA.
3. Chang, Kang-Tsung. 2006. Introduction to Geographic Information Systems. McGraw-Hill Higher Education, Columbus, Ohio, USA
4. Shamsi, U.M.. 2005. GIS Applications for Water, Wastewater, and Stormwater Systems
   CRC, Boca Raton, FL, USA
5. Jensen. J. R. 2004. Introductory Digital Image Processing. Prentice Hall, Inc., New Jersey, USA.
6. Bernhardsen, T., A. Viak and A. Norway. 2002. Geographic Information System: An Introduction. John Wiley & Sons Inc., New York, USA
7. Maidment, D. R. 2002. Arc Hydro: GIS for Water Resources. ESRI, Inc., USA.
8. Dijk, A. van, M. G. Bos. 2001. GIS and Remote Sensing Techniques in Land and Water Management. Springer, USA.
9. ICIMOD. 2001. Application of GIS and RS in Planning for Mountain Agriculture and Land Use Management. International Centre for Integrated Mountain Development (ICIMOD), Nepal
10. Lyon, J. G. 2001. Wetland Landscape Characterization: GIS, Remote Sensing and Image Analysis. CRC, Boca Raton, FL, USA.
11. Rees, W. G. 2001. Physical Principles of Remote Sensing (Topics in Remote Sensing) Cambridge University Press, UK.
12. Jensen, J. R. 2000. Remote Sensing of the Environment. Prentice Hall, New Jersey, USA.

WM-714 **WATER RESOURCES AND SUSTAINABLE DEVELOPMENT** 3 (3-0)

OBJECTIVE:

This course provides a synthesis and overview of the principles of sustainable development and to equip the students with a broad understanding of sustainable water resources development

THEORY:

Overview of sustainable development. Interrelation of water resources with other ecosystems and environment. Water quantity and water budget, system thinking to water resource management. Sustainable water resources development and environmental water management. Concept of Integrated Water Resources Management (IWRM). Water allocation and water scheduling problem, Equitable manners of water management. Concept of EIA study to water resource development. Local water organizations, world water organizations. History of water resources planning and sustainable development, Federal, provincial, and Local Government agencies involved in water resources planning and management, forecasting, future scenarios, population and other trends. Protocols employed at local, provincial, federal, regional and international levels. Plan formulation, evaluation, and implementation. Stakeholder involvement in planning processes. National and international case studies. Improving governance for the alleviation of poverty and resource degradation, empowerment of the poor and environmental sustainability, social and economic equity and sustainable development.

BOOKS RECOMMENDED:

1. Rooney, A. 2009. Sustainable Water Resources (How can we save our world?). Arcturus Publishing, New Delhi.
2. United Nations. 2007. Indicators of Sustainable Development: Guidelines and Methodologies Third Edition, United Nations, New York
3. Giupponi, C., D. A. J. Karssenberg, and P. H. Matt P. Hare. 2006. Sustainable Management of Water Resources: An Integrated Approach. Edward Elgar Publishing.
4. Warren Viessman Jr. and Timothy D. Feather. 2006. State Water Resources Planning in the United States," American Society of Civil Engineers, Reston, VA.
5. Loucks, D. P. and E. van Beek. 2005. Water Resources Systems Planning and Management: An Introduction to Methods, Models and Applications. UNESCO Publishing
6. Prasad K. 2003. Water Resources and Sustainable Development: Challenges of 21st Century. Shipra Publications, Delhi.
7. Vig, N. J. and Michael E. Kraft, 2003. Environmental Policy: New Directions for the Twenty-First Century, Fifth Edition. CQ Press, Washington, D.C.
8. Dzurik, A. A. 2002. Water Resources Planning. Rowman & Littlefield Publishers, Inc., Savage, Maryland.
9. Jauhari, V. P. 2002. Sustainable Development of Water Resources. Mittal Publications, Delhi.

10. Vig, N. J. and Regina S. Axelrod. 1999. The Global Environment: Institutions, Law and Policy. CQ Press, Washington, D.C.
11. Malcolm, N. 1997. Land, Water and Development. Routledge, London.
12. Mays, L.W. 1996. Water Resources Handbook, McGraw Hill.
13. Alvin S. Goodman, 1984. Water Resources Planning. Prentice Hall Inc., Englewood Cliffs, New Jersey.
14. Peterson, M. S. 1984. Water Resources Planning and Development. Prentice Hall Inc., Englewood Cliffs, New Jersey.
15. Grigg, N. S.1996. Water Resources Management. McGraw-Hill Book Co., New York.
16. ASCE. Sustainability Criteria for Water Resource Systems. American Society of Civil Engineers, Reston, VA.

WM-715 CLIMATE CHANGE AND WATER RESOURCES 3 (2-1)

OBJECTIVE:

To provide introduction to climate change, its causes and effects, knowledge about the green house process responsible for climate change. The course will help in understanding the impact of climate change on water resources

THEORY:

Atmospheric structure, overview of earth system processes, earth's energy balance, meso, micro, macro climate, atmospheric circulation and climate, clouds and climate, carbon cycle, anthropagenic and natural forcing, radiative forcing and global warming, greenhouse gases and green house effect history of past climate, recent climate change, carbon dioxide and energy use, surface temperature record, connections with our world, trend analysis of meteorological and oceanographic parameters, future predictions and impact, comparison of computer simulations of past climate with temperature records, computer projections of future climate change, the role of the hydrological cycle in the climate system, decade long precipitation variations and water resources, water availability and demand in south Asia, climate change and water resources, climate change and future water challenges, hydrologic models, global warming and the acceleration of the hydrological cycle, assessing of hydrology on regional and smaller scales, advantages and limitations of hydrologic models in climate, application of hydrologic models for climate change impact, application of models in Pakistan.

PRACTICAL:

Familiarization of general circulation models (GCM), atmospheric and oceanic GCM (AGCM and OGCM) along with sea-ice and land-surface components, regional climate system model, application of global climate models for weather forecasting and projecting climate change, hydrological models, coupled atmospheric–hydrologic models to forecast spatiotemporal variability of water resources, integration of a variety of fluid dynamical, chemical, and sometimes biological equations.

BOOKS RECOMMENDED:

1. Freeman, W. H. 2008. Earth's Climate: Past and Future. University of Virginia, USA.
2. Aguado, E. Burt, J. 2006. Understanding Weather and Climate. Prentice Hall, London.
3. Ahmad, Q. K. 2005. Climate Change and Water Resources in South Asia. CRC Press, Boca Raton, Florida, USA.
4. Garbrecht, J. and T. Piechota. 2005. Climate Variations, Climate Change, and Water Resources Engineering. American Society of Civil Engineers, USA.
5. Taylor, F. W. 2005. Elementary Climate Physics. Oxford University Press.
6. Kininmonth, W. 2004. Climate Change: A Natural Hazard, Multi-Science Publishing Co. Ltd.
7. Peixoto, J. P., Oort, A. H. 1992. Physics of Climate. Springer.
8. Oke, T. R. 1988. Boundary Layer Climates. Routledge.

WM-716 **WETLAND CONSERVATION AND MANAGEMENT** 3 (2-1)

OBJECTIVE:

To provide an overview of the natural processes of wetland environments, physical, biological and cultural aspects of wetlands and impact of humans on wetland and to learn how to manage wetlands

THEORY:

History of wetland science and management; significance, concept, types, functions, values and classification, elements of wetlands management. Managerial issues, stakeholders participation and case studies in wetlands of Pakistan. Wetlands identification, delineation, wetlands assessment and monitoring. Ecological survey design and sampling techniques. Wetlands and water quality. Natural wetland protection and riparian areas as buffers. Management of exempt wetland activities, restoration, creation and constructed wetlands. Ecosystem, biodiversity, ecology, ecology of streams and rivers, lake ecology. Fishpond management and fish parasites. Wetland and floodplain ecology, structure, functioning and special characteristics of tropical river and lake ecosystems. Investigating activities/processes in the watershed and its effects on freshwater ecosystems and relevant ecosystem services.

PRACTICAL:

Building a wetland filter. Water sampling at key wetlands sites. Field visits for ecological, mammal, plant, reptile, wildlife identification at key wetlands sites, insect and socio-economic, variations in different species at wetlands, evaluation and hydrological survey. Designing a management plan for wetland conservation

BOOKS RECOMMENDED:

1. Mitsch, W. J. and James G. Gosselink. 2007. Wetlands. John Wiley & Sons, Inc., Hoboken, New Jersey.
2. Boere, G., Galbraith, C. and Stroud, D. 2007. Water Birds around the World: A Global Overview of the Conservation, Management and Research of the World's Water Bird Flyways. Stationery Office (TSO) Scotland.
3. Batzer, D. P. and R. Sharitz. 2007. Ecology of Freshwater and Estuarine Wetlands. University of California Press.
4. Wallace, S. D. and Knight, R. L. 2006. Small Scale Constructed Wetland Treatment Systems: Feasibility, Design Criteria and O & M Requirements. Final Report, Water Environment Research Foundation, Alexandria, Virginia.
5. Falkenmark, M. and J. Rockstorm. 2004. Balancing Water for Humans and Nature. Earth scan, UK
6. Keddy, P. A. 2002. Wetland Ecology: Principles and Conservation. Cambridge University Press, UK.
7. Haslam, S. M. 2000. Understanding Wetlands: Fen, Bog and Marsh. Cambridge University Press, UK.
8. Weller, Milton W. 1999. Wetland Birds: Habitat, Resources and Conservation Implications. Cambridge University Press, UK.
9. Tiner, R. W. 1999. Wetland Indicators: A Guide to Wetland Identification, Delineation, Classification and Mapping. CRC Press, Boca Raton, Florida.
10. Moshiri, Gerald A. 1993. Constructed Wetlands for Water Quality Improvement. Wetland Sciences Incorporated, Florida, USA.

WM-717 SPECIAL TOPICS IN WATER MANAGEMENT 3 (3-0)

OBJECTIVE:

To provide the students the knowledge and understanding on topics of temporal or special interest in water management

THEORY:

They cover topics of temporal or special interest in water management which will not be made a regular on-going part of the curriculum**.** Experimental courses may also be offered as special topic courses and subsequently proposed as a regular course. Special topics must meet the same standard as academic credit course in every way.

BOOKS RECOMMENDED:

There is no specific book recommended for this course. Books, reports, journal and other research publications related to the topics selected for the course will be utilized.

Annexure - A

DETAILS OF COMPULSORY COURSES

COMPULSORY COURSES IN ENGLISH FOR Undergraduate Level

English I (Functional English) Credit Hrs. 3

Objectives: Enhance language skills and develop critical thinking.

Course Outlines

Basics of Grammar
Parts of speech and use of articles
Sentence structure, active and passive voice
Practice in unified sentence
Analysis of phrase, clause and sentence structure
Transitive and intransitive verbs
Punctuation and spelling

Comprehension
Answers to questions on a given text

Discussion
General topics and every-day conversation (topics for discussion to be at the discretion of the teacher keeping in view the level of students)

Listening
To be improved by showing documentaries/films carefully selected by subject teachers

Translation skills

Urdu to English

Paragraph writing
Topics to be chosen at the discretion of the teacher

Presentation skills
Introduction

Note: Extensive reading is required for vocabulary building

Books Recommended:

1. **Functional English**

a) Grammar
   1. Practical English Grammar by A.J. Thomson and A.V. Martinet. Exercises 1. Third edition. Oxford University Press. 1997. ISBN 0194313492
   2. Practical English Grammar by A.J. Thomson and A.V. Martinet. Exercises 2. Third edition. Oxford University Press. 1997. ISBN 0194313506

b) Writing
   1. Writing. Intermediate by Marie-Christine Boutin, Suzanne Brinand and Francoise Grellet. Oxford Supplementary Skills. Fourth Impression 1993. ISBN 0 19 435405 7 Pages 20-27 and 35-41.

c) Reading/Comprehension

1. Reading. Upper Intermediate. Brain Tomlinson and Rod Ellis. Oxford Supplementary Skills. Third Impression 1992. ISBN 0 19 453402 2.

d) Speaking

English II (Communication Skills) Credit Hrs. 3

Objectives: Enable the students to meet their real life communication needs.

Course Outlines

Paragraph writing
Practice in writing a good, unified and coherent paragraph

Essay writing
Introduction

CV and job application

Translation skills
Urdu to English

Study skills
Skimming and scanning, intensive and extensive, and speed reading, summary and précis writing and comprehension

Academic skills
Letter/memo writing, minutes of meetings, use of library and internet

Presentation skills
Personality development (emphasis on content, style and pronunciation)

Note: documentaries to be shown for discussion and review

Books Recommended:

Communication Skills

a) Grammar

1. Practical English Grammar by A.J. Thomson and A.V. Martinet. Exercises 2. Third edition. Oxford University Press 1986. ISBN 0 19 431350 6.

b) Writing

1. Writing. Intermediate by Marie-Chrisitine Boutin, Suzanne Brinand and Francoise Grellet. Oxford Supplementary Skills. Fourth Impression 1993. ISBN 019 435405 7 Pages 45-53 (note taking).
2. Writing. Upper-Intermediate by Rob Nolasco. Oxford Supplementary Skills. Fourth Impression 1992. ISBN 0 19 435406 5 (particularly good for writing memos, introduction to presentations, descriptive and argumentative writing).

c) Reading

1. Reading. Advanced. Brian Tomlinson and Rod Ellis. Oxford Supplementary Skills. Third Impression 1991. ISBN 0 19 453403 0.
2. Reading and Study Skills by John Langan
3. Study Skills by Riachard Yorky.

English III (Technical Writing and Presentation Skills) Crh. 3

Objectives: Enhance language skills and develop critical thinking

Course Outlines

Presentation skills

Essay writing
Descriptive, narrative, discursive, argumentative

Academic writing
How to write a proposal for research paper/term paper

How to write a research paper/term paper (emphasis on style, content, language, form, clarity, consistency)

Technical Report writing

Progress report writing

Note: Extensive reading is required for vocabulary building

Books Recommended:

Technical Writing and Presentation Skills

a) Essay Writing and Academic Writing
   1. Writing. Advanced by Ron White. Oxford Supplementary Skills. Third Impression 1992. ISBN 0 19 435407 3 (particularly suitable for discursive, descriptive, argumentative and report writing).
   2. College Writing Skills by John Langan. Mc=Graw-Hill Higher Education. 2004.
   3. Patterns of College Writing (4th edition) by Laurie G. Kirszner and Stephen R. Mandell. St. Martin's Press.

b) Presentation Skills

c) Reading
   The Mercury Reader. A Custom Publication. Compiled by norther Illinois University. General Editiors: Janice Neulib; Kathleen Shine Cain; Stephen Ruffus and Maurice Scharton. (A reader which will give students exposure to the best of twentieth century literature, without taxing the taste of engineering students).

ISLAMIC STUDIES
(Compulsory)

Objectives:

This course is aimed at:

1 To provide Basic information about Islamic Studies
2 To enhance understanding of the students regarding Islamic Civilization
3 To improve Students skill to perform prayers and other worships
4 To enhance the skill of the students for understanding of issues related to faith and religious life.

Course Outlines:

Introduction to Quranic Studies

1) Basic Concepts of Quran
2) History of Quran
3) Uloom-ul -Quran

Study of Selected Text of Holly Quran

1) Verses of Surah Al-Baqra Related to Faith(Verse No-284-286)
2) Verses of Surah Al-Hujrat Related to Adab Al-Nabi (Verse No-1-18)
3) Verses of Surah Al-Mumanoon Related to Characteristics of faithful (Verse No-1-11)
4) Verses of Surah al-Furqan Related to Social Ethics (Verse No.63-77)
5) Verses of Surah Al-Inam Related to Ihkam(Verse No-152-154)

Study of Selected Text of Holly Quran

1) Verses of Surah Al-Ihzab Related to Adab al-Nabi (Verse No.6,21,40,56,57,58.)
2) Verses of Surah Al-Hashar (18,19,20) Related to thinking, Day of Judgment
3) Verses of Surah Al-Saf Related to Tafakar,Tadabar (Verse No-1,14)

Seerat of Holy Prophet (S.A.W) I

1) Life of Muhammad Bin Abdullah (Before Prophet Hood)
2) Life of Holy Prophet (S.A.W) in Makkah
3) Important Lessons Derived from the life of Holy Prophet in Makkah

Seerat of Holy Prophet (S.A.W) II

1) Life of Holy Prophet (S.A.W) in Madina
2) Important Events of Life Holy Prophet in Madina
3) Important Lessons Derived from the life of Holy Prophet in Madina

Introduction To Sunnah

1) Basic Concepts of Hadith
2) History of Hadith
3) Kinds of Hadith
4) Uloom –ul-Hadith
5) Sunnah & Hadith
6) Legal Position of Sunnah

Selected Study from Text of Hadith

Introduction To Islamic Law & Jurisprudence

1) Basic Concepts of Islamic Law & Jurisprudence
2) History & Importance of Islamic Law & Jurisprudence
3) Sources of Islamic Law & Jurisprudence
4) Nature of Differences in Islamic Law
5) Islam and Sectarianism

Islamic Culture & Civilization

1) Basic Concepts of Islamic Culture & Civilization
2) Historical Development of Islamic Culture & Civilization
3) Characteristics of Islamic Culture & Civilization
4) Islamic Culture & Civilization and Contemporary Issues

Islam & Science

1) Basic Concepts of Islam & Science
2) Contributions of Muslims in the Development of Science
3) Quranic & Science

Islamic Economic System

1) Basic Concepts of Islamic Economic System
2) Means of Distribution of wealth in Islamic Economics
3) Islamic Concept of Riba
4) Islamic Ways of Trade & Commerce

Political System of Islam

1) Basic Concepts of Islamic Political System
2) Islamic Concept of Sovereignty
3) Basic Institutions of Govt. in Islam

Islamic History

1) Period of Khlaft-E-Rashida
2) Period of Ummayyads
3) Period of Abbasids

Social System of Islam

1) Basic Concepts of Social System of Islam
2) Elements of Family
3) Ethical Values of Islam

Books Recommended:

1) Hameed ullah Muhammad, “Emergence of Islam” , IRI, Islamabad
2) Hameed ullah Muhammad, “Muslim Conduct of State”
3) Hameed ullah Muhammad, ‘Introduction to Islam
4) Mulana Muhammad Yousaf Islahi,”
5) Hussain Hamid Hassan, “An Introduction to the Study of Islamic Law” leaf Publication Islamabad, Pakistan.
6) Ahmad Hasan, “Principles of Islamic Jurisprudence” Islamic Research Institute, International Islamic University, Islamabad (1993)
7) Mir Waliullah, “Muslim Jrisprudence and the Quranic Law of Crimes” Islamic Book Service (1982)
8) H.S. Bhatia, “Studies in Islamic Law, Religion and Society” Deep & Deep Publications New Delhi (1989)
9) Dr. Muhammad Zia-ul-Haq, “Introduction to Al Sharia Al Islamia” Allama Iqbal Open University, Islamabad (2001)

Annexure - C

Pakistan Studies (Compulsory)

Introduction/Objectives

- Develop vision of historical perspective, government, politics, contemporary Pakistan, ideological background of Pakistan.
- Study the process of governance, national development, issues arising in the modern age and posing challenges to Pakistan.

Course Outline

1. **Historical Perspective**
   a. Ideological rationale with special reference to Sir Syed Ahmed Khan, Allama Muhammad Iqbal and Quaid-i-Azam Muhammad Ali Jinnah.
   b. Factors leading to Muslim separatism
   c. People and Land
      i. Indus Civilization
      ii. Muslim advent
      iii. Location and geo-physical features.
2. **Government and Politics in Pakistan**

   Political and constitutional phases:
   a. 1947-58
   b. 1958-71
   c. 1971-77
   d. 1977-88
   e. 1988-99
   f. 1999 onward
3. **Contemporary Pakistan**
   a. Economic institutions and issues
   b. Society and social structure
   c. Ethnicity
   d. Foreign policy of Pakistan and challenges
   e. Futuristic outlook of Pakistan

Books Recommended

1. Burki, Shahid Javed. *State & Society in Pakistan,* The Macmillan Press Ltd 1980.
2. Akbar, S. Zaidi. *Issue in Pakistan's Economy.* Karachi: Oxford University Press, 2000.
3. S.M. Burke and Lawrence Ziring. Pakistan's Foreign policy: An Historical analysis. Karachi: Oxford University Press, 1993.
4. Mehmood, Safdar. *Pakistan Political Roots & Development.* Lahore, 1994.
5. Wilcox, Wayne.*The Emergence of Banglades.,* Washington: American Enterprise, Institute of Public Policy Research, 1972.
6. Mehmood, Safdar. *Pakistan Kayyun Toota,* Lahore: Idara-e-Saqafat-e-Islamia, Club Road, nd.
7. Amin, Tahir. *Ethno - National Movement in Pakistan,* Islamabad: Institute of Policy Studies, Islamabad.
8. Ziring, Lawrence. *Enigma of Political Development.* Kent England: WmDawson & sons Ltd, 1980.

9. Zahid, Ansar. *History & Culture of Sindh.* Karachi: Royal Book Company, 1980.
10. Afzal, M. Rafique. *Political Parties in Pakistan,* Vol. I, II & III. Islamabad: National Institute of Historical and cultural Research, 1998.
11. Sayeed, Khalid Bin. *The Political System of Pakistan.* Boston: Houghton Mifflin, 1967.
12. Aziz, K.K. *Party, Politics in Pakistan,* Islamabad: National Commission on Historical and Cultural Research, 1976.
13. Muhammad Waseem, Pakistan Under Martial Law, Lahore: Vanguard, 1987.
14. Haq, Noor ul. *Making of Pakistan: The Military Perspective.* Islamabad: National Commission on Historical and Cultural Research, 1993.

Annexure - D

COMPULSORY MATHEMATICS COURSES FOR B.Sc (Hons) AGRICULTURE

1. MATHEMATICS I (ALGEBRA)

Prerequisite(s): Mathematics at secondary level

Credit Hours: 3 + 0

Specific Objectives of the Course: To prepare the students, not majoring in mathematics, with the essential tools of algebra to apply the concepts and the techniques in their respective disciplines.

Course Outline:

Preliminaries: Real-number system, complex numbers, introduction to sets, set operations, functions, types of functions.

Matrices: Introduction to matrices, types, matrix inverse, determinants, system of linear equations, Cramer's rule.

Quadratic Equations: Solution of quadratic equations, qualitative analysis of roots of a quadratic equations, equations reducible to quadratic equations, cube roots of unity, relation between roots and coefficients of quadratic equations.

Sequences and Series: Arithmetic progression, geometric progression, harmonic progression.

Binomial Theorem: Introduction to mathematical induction, binomial theorem with rational and irrational indices.

Trigonometry: Fundamentals of trigonometry, trigonometric identities.

Books Recommended:

Dolciani MP, Wooton W, Beckenback EF, Sharron S, *Algebra 2 and Trigonometry*, 1978, Houghton & Mifflin,

Boston (suggested text)
Kaufmann JE, College *Algebra and Trigonometry*, 1987, PWS-Kent Company, Boston
Swokowski EW, *Fundamentals of Algebra and Trigonometry* (6^{th} edition), 1986, PWS-Kent Company, Boston

2. MATHEMATICS II (CALCULUS)

Prerequisite(s): Mathematics I (Algebra)

Credit Hours: 3 + 0

Specific Objectives of the Course: To prepare the students, not majoring in mathematics, with the essential tools of calculus to apply the concepts and the techniques in their respective disciplines.

Course Outline:

Preliminaries: Real-number line, functions and their graphs, solution of equations involving absolute values, inequalities.

Limits and Continuity: Limit of a function, left-hand and right-hand limits, continuity, continuous functions.

Derivatives and their Applications: Differentiable functions, differentiation of polynomial, rational and transcendental functions, derivatives.
Integration and Definite Integrals: Techniques of evaluating indefinite integrals, integration by substitution, integration by parts, change of variables in indefinite integrals.

Books Recommended:

Anton H, Bevens I, Davis S, *Calculus: A New Horizon* (8th edition), 2005, John Wiley, New York
Stewart J, *Calculus* (3rd edition), 1995, Brooks/Cole (suggested text)
Swokowski EW, *Calculus and Analytic Geometry*, 1983, PWS-Kent Company, Boston
Thomas GB, Finney AR, *Calculus* (11th edition), 2005, Addison-Wesley, Reading, Ma, USA

3. MATHEMATICS III (GEOMETRY)

Prerequisite(s): Mathematics II (Calculus)

Credit Hours: 3 + 0

Objectives: To prepare the students, not majoring in mathematics, with the essential tools of geometry to apply the concepts and the techniques in their respective disciplines.

Course Outline:

Geometry in Two Dimensions: Cartesian-coördinate mesh, slope of a line, equation of a line, parallel and perpendicular lines, various forms of equation of a line, intersection of two lines, angle between two lines, distance between two points, distance between a point and a line.

Circle: Equation of a circle, circles determined by various conditions, intersection of lines and circles, locus of a point in various conditions.
Conic Sections: Parabola, ellipse, hyperbola, the general-second-degree equation

Books Recommended:

Abraham S, Analytic Geometry, Scott, Freshman and Company, 1969
Kaufmann JE, College *Algebra and Trigonometry*, 1987, PWS-Kent Company, Boston
Swokowski EW, *Fundamentals of Algebra and Trigonometry* (6th edition), 1986, PWS-Kent Company, Boston

Note:

1. ***Two courses will be selected from the following three courses of Mathematics.***

2. ***Universities may make necessary changes in the courses according to the requirement as decided by the Board of Studies.***

Annexure - E

Statistics-I

Credit 3 (2-1)

Definition and importance of Statistics in Agriculture, Data Different types of data and variables

Classification and Tabulation of data, Frequencey distirbtuion, stem-and-Leaf digram, Graphical representation of data Histogram, frequesncey polygon, frequency curve.

Measure of Central tendency, Definition and calcutiaon of Arithmetic mean, Geometric mean, Harmonic mean, Median quantiles and Mode in grouped and ungruped data.

Measure of Dispersion, Definition and Calculation of Range, quartile deviation, Mean deviation, Standard deviation and variance, coefficient of variation.

Practicals

a. Frequency Distribution
b. Stem-and-Leaf digram
c. Various types of Graphs
d. Mean, Geometric mean Harmonic Mean,
e. Median, Quartiles Deviation, mean Deviation.
f. Standard Deviation, Variance, Coefficient of variation,
g. Skewness and kenosis

Book Recommended

1. Introduction to Statistical Theory Part- I by Sher Muhammad and Dr. Shahid Kamal (Latest Edition)
2. Statistical Methods and Data Analysis by Dr. Faquir Muhammad
3. A. Concise Course in A. Level Statistic with world examples by J. Crawshaw and J. Chambers (1994)
4. Basic Statistics an Inferential Approach 2nd Ed. (1986) Fran II. Dietrich-II and Thomes J. Keans

Statistics-II

Credit 3 (2-1)

Sampling Probability and non-Probability Sampling, Simple random sampling stratified random sampling Systematic sampling error, Sampling distribution of mean and difference between two means. Interference Theory: Estimation and testing of hypothesis, Type—I and type-II error, Testing of hypothesis about mean and difference between two means using Z-test and t-test, Paired t-test, Test of association of attributes using X2 (chi-square) Testing hypothesis about variance.

Practicals

a. Sampling random sampling
b. Stratified random sampling.
c. Sampling distribution of mean
d. Testing of hypotheses regarding population mean
e. Testing of hypotheses about the difference between population means
f. Chi-square test
g. Testing of Correlation Coefficient
h. Fitting of simple linear regression
i. One-way ANOVA
j. Two-way ANOVA

Book Recommended

1. Introduction to Statistical Theory Part-II by Sher Muhammad and Dr. Shahid Kamal (Latest Edition)
2. Statistical Methods and Data Analysis by Dr. Faquir Muhammad
3. Principles and Procedures of Statistics A Bio-meterial approach, 2nd Edition, 1980 by R.G.D Steal and James H. Tarric
4. Statistical Procedures for Agricultural Research 2nd Edition (1980) by K.A. Gomez and A.A. Gomez

Note: Universities may make necessary changes in the courses according to the requirement as decided by the Board of Studies.

Course Name: **Introduction to Information and Communication Technologies**

Course Structure: Lectures: 2 Labs: 1 **Credit Hours:** 3
Pre-requisite: None **Semester: 1**

Course Description:

This is an introductory course on Information and Communication Technologies. Topics include ICT terminologies, hardware and software components, the internet and world wide web, and ICT based applications. After completing this course, a student will be able to:

- Understand different terms associated with ICT
- Identify various components of a computer system
- Identify the various categories of software and their usage
- Define the basic terms associated with communications and networking
- Understand different terms associated with the Internet and World Wide Web.
- Use various web tools including Web Browsers, E-mail clients and search utilities.
- Use text processing, spreadsheets and presentation tools
- Understand the enabling/pervasive features of ICT

Course Contents:

: Basic Definitions & Concepts
: Hardware: Computer Systems & Components
: Storage Devices, Number Systems
: Software: Operating Systems, Programming and Application Software
: Introduction to Programming, Databases and Information Systems
: Networks
: Data Communication
: The Internet, Browsers and Search Engines
: The Internet: Email, Collaborative Computing and Social Networking
: The Internet: E-Commerce
: IT Security and other issues
: Project Week
: Review Week

Text Books/Reference Books:

Introduction to Computers by Peter Norton, 6th International Edition (McGraw HILL)
Using Information Technology: A Practical Introduction to Computer & Communications by Williams Sawyer, 6th Edition (McGraw HILL)
Computers, Communications & information: A user's introduction by Sarah E. Hutchinson, Stacey C. Swayer
Fundamentals of Information Technology by Alexis Leon, Mathewsleon Leon Press.

Functional Biology-I
Credit Hours 3+0

Biological Methods

Principles of Cellular Life
Chemical Basis
Structure and Function
Principles of Metabolism
Energy Acquisition

Principles of Inheritance
Mitosis and Meiosis
Chromosomes
Observable Inheritance Patterns
DNA Structure and Function
RNA and Proteins
Genes
Genetic Engineering and Biotechnology

Biodiversity
Fundamental Concept of Biodiversity
One or two examples of each of the following from commonly found organism
Prions
Viruses
Bacteria
Protistans
Algae
Fungi
Plants
Crops
Animals
Invertebrates
Vertebrates

Reading

1. Roberts, M.M., Reiss and G.Monger. 2000. Advanced Biology, Nelson.
2. Starr, C, and R, Taggart, 2001. Biology: The Unity and Diversity of Life Brooks and Cole.
3. Campbell, N.A., J.B, Reece, L.G. Mitchell, M.R, Taylor. 2001. Biology: Concepts and Connections. Prentice-Hall.

Functional Biology-II

Credit Hours 3+0

Myths and Realities of Evolution

Microevolution
Speciation
Macroevolution

Level of Organization
- Plants
  - Tissues
  - Nutrition and Transport
  - Reproduction
  - Growth and Development

- Animals
  - Tissue, Organ System and Homeostasis
  - Information Flow and Neuron
  - Nervous System
  - Circulation and Immunity
  - Nutrition and Respiration
  - Reproduction and Development

- Ecology and Behavior
  - Ecosystems
  - Biosphere
  - Social Interactions
  - Community Interactions
  - Human Impact on Biosphere
  - Environment Conservation

Reading

1. Roberts, M.M., Reiss and G.Monger. 2000. Advanced Biology, Nelson.
2. Starr, C, and R, Taggart, 2001. Biology: The Unity and Diversity of Life Brooks and Cole.
3. Campbell, N.A., J.B, Reece, L.G. Mitchell, M.R, Taylor. 2001. Biology: Concepts and Connections. Prentice-Hall.

Note: Universities may make necessary changes in the courses according to the requirement as decided by the Board of Studies.

GENERAL RECOMMENDATIONS

The committee appreciated the role of HEC in improving higher education in the country. The participants of the National Curriculum Revision Committee of water management formulated the following recommendations.

1. HEC should arrange training of faculty members on the newly developed courses on priority basis.

2. Short refresher courses/workshops pertaining to teaching methods and information technology should be arranged for improvement of teaching skills.

3. Books (text, reference, digital) and software (water related) should be provided to the universities.

4. Curriculum should be updated after every five years.

5. Funds should be allocated for collaboration among various institutes/universities.

6. Higher Education Commission should arrange training of the in-service young faculty through using the capabilities and expertise of the senior/retired faculty for the areas where universities feel deficiency.

7. HEC should ensure availability of minimum two copies of all recommended book to the departmental libraries of all the agricultural universities of the country.

8. The committee recommends that periodic inter-university/inter-provinces visits of faculty members should be made compulsory to enhance the exchange of views and observe the site specific technology developed in different provinces/universities.

9. The committee requests the HEC to review the policy of lab establishment funding with priority for the proposal relevant to practical facilities of the newly developed courses being offered at different institutions.