



Department of Irrigation and Drainage
Engineering
Mahatma Phule Krishi Vidyapeeth
Rahuri-413 722, Dist. Ahmednagar (MS)



Doctoral Programme in Irrigation and Drainage Engineering

Course Layout

Minimum Credit Requirements

Sr. No.	Subject	Minimum credit(s)
1	Major	15
2	Minor	08
3	Supporting	05
4	Seminar	02
5	Research	45
	Total credits	75
	Non credit compulsory courses*	06

Sr. No.	Course Number	Course Title	Credits
A) Major Subjects (Min. 15 credits)			
1.	IDE 601*	Advanced Hydromechanics in Soil Aquifer Systems	3(3+0)
2.	IDE 602 *	Advances in Irrigation and Drainage	2(2+0)
3.	IDE 603	Hydro-Chemical Modelling and Pollutant Management	3(3+0)
4.	IDE 604	Plant Growth Modelling and Simulation	3(3+0)
5.	IDE 605	Pipe Network Analysis	3(2+1)
6.	IDE 606	River Basin Models	3(1+2)
7.	IDE 607	Ground Water Geology and Geophysics	3(2+1)
8.	IDE 608	Soft Computing in Water Resources	3(2+1)
9.	IDE 609	Advances in GIS and Remote Sensing for Land and	3(2+1)

		Water Resources Management	
10.	IDE 610	Risk Management in Water resources	3(2+1)
11.	IDE 611	Water Resources Economics and Auditing	3(2+1)
12.	IDE 693*	Special Problem	1(0+1)
13.	IDE 694*	Case Study	1(0+1)

* Compulsory

B) Minor Subjects (Min. 8 credits)

1.	AE 601	Environmental Impact Assessment	3(1+2)
2.	AE 602	Climate Change Impact, Adaptation and Mitigation	3(2+1)
3.	AE 603	Research Techniques	3(2+1)
4.	AE 604	Bench Marking and performance Analysis	3(2+1)
5	SWCE 605	Hydrological Models	3(2+1)

C) Supporting Courses (Min. 5 credits)

1.	BSCT 601	Object Oriented Programming	3(2+1)
2.	MATH 601	Mathematical Modelling and Software Applications	3(1+2)
3.	STAT 609	Operations Research	3(2+1)
4.	STAT 610	Probabilistic Approach in Design	2(2+0)
5.	STAT 611	Geostatistical Analysis	2(1+1)

D) Seminar (2 credits)

1.	IDE 691	Seminar I	1(0+1)
2.	IDE 692	Seminar II	1(0+1)

E) Doctoral Research (45 credits)

1.	IDE 699	Doctoral Research	45(0+45)
----	---------	-------------------	----------

F) Non Credit Compulsory Courses*

1.	PGS 501	Library and Information Services	1(0+1)
2.	PGS 502	Technical Writing and Communications Skills	1(0+1)
3.	PGS 503 (e-Course)	Intellectual Property and its Management in Agriculture	1(1+0)
4.	PGS 504	Basic Concepts in Laboratory Techniques	1(0+1)
5.	PGS 505 (e-Course)	Agricultural Research, Research Ethics and Rural Development Programmes	1(1+0)
6.	PGS 506 (e-Course)	Disaster Management	1(1+0)

* exempted if completed in Master's degree

Course Content

IDE- 601*	Advanced Hydro-mechanics in Soil Aquifer Systems	3(3+0)
------------------	---	---------------

Theory:

UNIT I

Soil aquifer system. Flow of water in partially saturated soils. Partial differential equation of flow.

UNIT II

Determination of unsaturated hydraulic conductivity and models for its estimation.

UNIT III

Infiltration and exfiltration from soils in absence and presence of water table. Movement of groundwater in fractured and swelling porous media.

UNIT IV

Spatial variability. Theory of krigging. Statistical approaches in soil water dynamics

Suggested Books:

Kirkham & Powers.1972. Advanced Soil Physics. John Wiley & Sons.

Muskut M.1937. The Flow of Homogeneous Fluid through Porous Media. McGraw Hill.

IDE- 602*	Advances in Irrigation and Drainage	2(2+0)
------------------	--	---------------

Theory:

UNIT I

Advances in surface irrigation systems- surge irrigation: effect of surging on surface flow hydraulics, cablegation: water supply management.

UNIT II

Atomization in sprinkler and micro irrigation system; multipurpose and special uses of micro irrigation.

UNIT III

Synthetic materials for drainage systems. Environmental issues related to drainage. Socio-economic impacts of drainage systems.

UNIT IV

Controlled drainage for reducing agricultural non point pollution. Application of simulation models for drainage systems.

Suggested Books;

FAO. 1982. Mechanized Sprinkler Irrigation. FAO Irrigation & Drainage Paper 35.

FAO. 1989. Guidelines for Designing and Evaluating Surface Irrigation System. FAO Irrigation & Drainage Paper 45.

Keller J & Bliesner RD. 1990. Sprinkler and Trickle Irrigation. Chapman & Hall.
Ritzema HP. (Ed.). 1994. Drainage Principles and Applications. ILRI.
Walker WR & Skogerboe GV. 1987. Surface Irrigation: Theory and Practice. Prentice Hall

IDE- 603	Hydro-Chemical Modelling and Pollutant Management	3(3+0)
-----------------	--	---------------

Theory:

UNIT I

Hydrodynamics in flow through porous media, Hydrodynamic dispersion, diffusion, convection equation.

UNIT II

Analytical and numerical models of contaminant transport in unsaturated soil profile and ground water.

UNIT III

Water quality management in lakes and reservoirs; physical characteristics; hydrologic and chemical budgets; bio-geochemical processes of pollutants; assessment methods.

UNIT IV

Classical wastewater problems; Water reclamation, reuse, water quality constraints and considerations for reuse in irrigation and industry; Biological wastewater treatment.

UNIT V

Modern stream pollution problem. Quality of groundwater and sources of contaminants. Cost economics – environment impact assessment.

Suggested Books:

Larry W Mays 1996. Water Resources Handbook. McGraw Hill.
Metcalf and Eddy 1994. Wastewater Treatment Engineering and Reuse. John Wiley.
Soli J Arceivala 1998. Wastewater Treatment for Pollution Control. Tata, McGraw-Hill.

IDE- 604	Plant Growth Modelling and Simulation	3(3+0)
-----------------	--	---------------

Theory:

UNIT I

Introduction to crop growth modeling. Simulation and simulation techniques. Types of models and modeling approaches.

UNIT II

Relational diagram for principal process, structures of a generalized agricultural simulator.

UNIT III

Input environment and techniques of monitoring plant environment, process and aspect of growth and development. Input yield models.

UNIT IV

Quantitative analysis of plant processes light photo-syntheses, respiration, growth, water uptake etc. and their mathematical modeling.

Suggested Books:

Loomis RS, Connor DJ.1992. Crop Ecology: Productivity and Management in Agricultural System. Cambridge Univ. Press.

Spedding CRW. 1979. An Introduction to Agricultural Systems. Applied Science Publ.

Thornley JHM & Johnson IR. 1990. Plant and Crop Modelling. A Mathematical Approach to Plant and Crop Physiology. Clarendon Press. Oxford Science Publ.

IDE- 605

Pipe Network Analysis

3(2+1)

Theory:

UNIT I

Introduction to pipe network, Components of piped systems and pipe material selection, bedding and laying. Type of water supply system, type of piping system, type of water distribution network, labeling network elements, network components, design requirements and problems. Basic hydraulic principles, energy and hydraulic grade lines, functional head losses in pipe, minor head losses, equivalent pipes.

UNIT II

Economic principle, cash flow diagram and methods of analysis, cost functions.

UNIT III

Optimization: principles and its application in network analysis.

UNIT IV

Reservoir, Pumps and Valves:

Types of reservoir, service and balancing reservoir, three and multiple reservoir systems.

Pumps: system head–discharge curve and pump head-discharge curve, pump characteristics, Pump combination, valves on pipe network.

UNIT V

Network parameters and types of analysis.

Network parameters, parameter interrelationship, formulation of equations

Types of analysis- Hardy cross method other analysis methods for branched and looped network . Network models: minimal spanning tree algorithm, shortest route problem, maximum flow model., Optimal layout, Network design for special cases

Practical:

Pipe network analysis for branched network by Hardy-Cross method

Pipe network analysis for looped network by Hardy-Cross method

Optimal design of rising main for irrigation network.

Optimal design of branched network using LP, Successive pipe size reduction method.

Optimal layout using network models (TORA).
 Optimal design of looped network using LP, Successive pipe size reduction method.
 Optimal design of pumped network.
 Optimal design of gravity network.

Suggested Books

Bhave, P.R. 2003. Optimal Design of Water Distribution Networks. Narosa Publishing House, New Delhi.
 Taha, H.A. 2007. Operations Research an Introduction (eighth Ed.). Prentice-Hall of India Private Limited, New Delhi.
 Bhave, P.R. and Gupta R. 2006. Analysis of Water Distribution Networks. Narosa Publishing House, New Delhi.
 Trifunovic, N. 2006. Introduction to urban water distribution, Taylor & Francis/Balkema
 Brandon, Thomas W. 1984. Water distribution systems. Institution of Water Engineers and Scientist.

IDE- 606	River Basin Models	3(1+2)
-----------------	---------------------------	---------------

Theory:

UNIT I

The processes in river basin models; their conceptualisation and need for modeling, the processes of data collection, model validation and calibration.

UNIT II

Integrated surface water and groundwater modelling

MIKE SHE Model: The hydrologic processes simulated by MIKE SHE

The mechanisms used to couple the hydrologic processes in MIKE SHE

Basic hydraulic flow modelling in streams and canals using MIKE 11

Setting up a model in MIKE SHE

Evaluation of results of an integrated groundwater/surface water model

Calibration strategies for an integrated model, including a brief introduction to automatic calibration tools

UNIT III

River Basin Modelling

MIKE Basin Model: General introduction to river basin management

Introduction to processes described in MIKE BASIN

Defining and conceptualising the problem scenarios

MIKE BASIN Graphical User Interface (GUI)

Model schematisation

Introduction to the MIKE BASIN process descriptions

Data management incl. Temporal Analyst

Result analysis and presentation (including statistical analysis and results interpretation)

Assessing water demands for water supply, irrigation and hydropower

Reservoir operation

Development of simple models

UNIT IV

Introduction to river and channel modelling

MIKE 11 Model: Theoretical background to hydrodynamic modelling

Model build

Understanding data requirements

Working with editors for network, cross section and time series data

Defining boundary conditions and estimating parameters

Running simulations and understanding the results

Introduction to structures

UNIT V

Finite Element Model for Flow and Mass/Heat Transport in Sat/Unsat Porous Media

FEFLOW Model: Groundwater modeling for

Density-dependent flow (salt water intrusion)

Transient or steady-state flow

Saturated and unsaturated flow

Multiple free surfaces (perched water table)

Mass and heat transport

Practical:

Exercises with case studies for validation, calibration and use of MIKE SHE model for water resources

Exercises with case studies for validation, calibration and use of MIKE BASIN model for water resources

Exercises with case studies for validation, calibration and use of MIKE 11 model for water resources

Exercises with case studies for validation, calibration and use of FEFLOW model for water resources

Suggested Books

DHI.2005. MIKE-SHE: An Integrated Hydrological Modelling System. DHI Water and Environment, Agern Alle 5, DK- 2970, Horsholm, Denmark, 454 PP.

DHI.2004. MIKE 11: A Modelling System for Rivers and Channels. DHI Water and Environment, Agern Alle 5, DK – 2970, Horsholm, Denmark, 454 pp.

DHI.2005. MIKE ZERO: Preprocessing and Postprocessing. DHI Water and Environment, Agern Alle 5, DK – 2970, Horsholm, Denmark, 457 pp.

DHI.2005. MIKE-SHE: An Integrated Hydrological Modelling System. DHI Water and Environment, Agern Alle 5, DK – 2970, Horsholm, Denmark, 149 pp. (Exercise)

DHI.2004. MIKE View: A Results Presentation Tools for MOUSE, MIKE SWMM, MIKE NET and MIKE 11. DHI Water and Environment, Agern Alle 5, DK – 2970, Horsholm, Denmark, 130 pp.

DHI.2004. MIKE 11: A Modelling System for Rivers and Channels. DHI Water and Environment, Agern Alle 5, DK – 2970, Horsholm, Denmark, 1-1: 9-14 pp. (Exercise)
DHI.2004. MIKE Basin: River Basin Modelling. DHI Water and Environment, Agern Alle 5, DK – 2970, Horsholm, Denmark
Technical and User Manual of FEFLOW
Technical and User Manuals of MIKE SHE, MIKE 11 and MIKE Basin models.

IDE- 607	Ground Water Geology and Geophysics	3(2+1)
-----------------	--	---------------

Theory:

UNIT I

Storage and conduit functions of rocks, geologic controls on ground water, ground water provinces of India.

UNIT II

Introduction to geology of Maharashtra with reference to ground water occurrence, physical geology and ground water regime in basaltic rock terrain

UNIT III

Principles of Geophysical methods for ground water exploration: Magnetic method, magnetic properties of rocks, geomagnetic field, modern magneto meters, survey layout and field procedure, qualitative and quantitative interpretation.

UNIT IV

Gravitational method, gravimeters, field procedure, corrections to gravity observations- Bouguer anomaly, density determinations, theoretical aspects of gravity interpretation, depth determination.

UNIT V

Electrical method: self potential method, earth resistivity, point electrode configurations, vertical electrical sounding, layered earth, type curves, VES interpretation, electrical mapping, anisotropic earth.

UNIT VI

Well logging in oil fields, Permeability zone logs: resistivity and conductivity logs, porosity logs.

Practical:

Use of magneto meters for ground water exploration,
Use of gravimeters for ground water exploration,
Use of resistivity meters for ground water exploration,
Preparation of resistivity logs and interpretation about ground water status

Suggested Books:

Parasnis, D.S. 1986. Principles of Applied Geophysics. Chapman and Hall, New York.

- Dhokarikar, B.G. 1991. Groundwater resource development in basaltic rock terrain of Maharashtra. Water Industry Publication, Pune-51.
- Karant, K.R. 1987. Ground water Assessment, Development and Management. Tata McGraw-Hill Publishing Co. Ltd., New Delhi.
- Hantush, M.S. Groundwater Hydrology, McGraw Hill
- Walton, W.C. 1978. Groundwater Resources Evaluation. McGraw Hill

IDE-608

Soft Computing in Water Resources

3(2+1)

Theory:

UNIT I

Data driven investigation in hydrology

Unified Modeling Language: What is UML?, The Framework of the UML, Object Model Diagrams, Database Design and Deployment.

Digital Library Technology: Introduction, Building the Hydrologic Information System Digital Library

Hydrologic Metadata: Introduction to Metadata, Definition of Metadata Categories, Metadata: Problems and Standardization, Hydrologic Metadata

Hydrologic Data Models: Data Models, Geodata Models, The ArcHydro Data Model

Modelshed Data Model: Modelshed Framework, The Modelshed Geodata Model Structure

UNIT II

Managing and accessing large data sets

Data Models for Storage and Retrieval: Survey of Different Types and Uses of Data, Who are the Users?, Gathering, Using, and Archiving Data, Data Management Challenges

Data Formats: Formats and Abstraction Layers, Concepts of Data File Formats, Hierarchical Data Format (HDF5) data model

UNIT III

Data communication and data processing and analysis

UNIT IV

Statistical Data Mining: Supervised Learning, Unsupervised Learning

Neural Networks: Introduction, Methods, Back-Propagation Neural Networks, Synthetic Data Generation Based on Neural Networks

Genetic Algorithms: Introduction, GA Basics, Methods; other evolutionary algorithms.

Fuzzy Logic: Introduction, Fuzzy Sets Essentials, Fuzzy Modeling, Methods

Bayesian Networks

Practical:

Data driven investigations in hydrology

Managing and accessing large data sets
 Data communication and data processing and analysis
 Application of artificial neural network in water resources
 Application of Genetic and other evolutionary algorithms in water resources
 Application of fuzzy logic in water resources
 Application of Bayesian Networks in water resources

Suggested Books:

Pratihari, D.K. 2008. Soft Computing. Narosa Publications.
 Praveen Kumar and Marukus. 2005. Hydroinformatics: Data Integrative Approaches in Computation, Analysis, and Modeling. CRC Press, Taylor and Francis Group.
 Robert J. Abrahart; Linda M. See; Dimitri P. Solomatine. 2008. Practical Hydroinformatics. Springer Publications
 Kishan Mehrotra, Chilukuri K. Mohan and Sanjay Ranka. 1996. Elements of Artificial Neural Networks. The MIT Press.
 Melanie Mitchell. 1998. An Introduction to Genetic Algorithms. The MIT Press
 Thomas Bäck. 1996. Evolutionary algorithms in theory and practice: evolution strategies, evolutionary programming, genetic algorithms. Oxford University Press.
 Sakawa, Masatoshi. 2001. Genetic Algorithms and Fuzzy Multiobjective Optimization. Operations Research/Computer Science Interfaces Series. Springer Publications.
 Randy L. Haupt. 2004. Practical genetic algorithms. Wiley-IEEE
 Kazuo Tanaka, Tak Niimura. 1996. An Introduction to Fuzzy Logic for Practical Applications. Springer Verlag.
 Masao Mukaidono, Hiroaki Kikuchi. 2001. Fuzzy Logic for Beginners. World Scientific Pub Co Inc.
 Vilem Novak, Jiri Mockor, Irina Perfilieva. 1999. Mathematical Principles of Fuzzy Logic. Kluwer Academic Pub.

IDE- 609	Advances in GIS and Remote Sensing for Land and Water Resource Management	3(2+1)
-----------------	--	---------------

Theory:

UNIT I

Remote sensing, photogrammetry and GIS: fundamentals, concepts and applications

UNIT II

Electromagnetic spectrum. Energy interaction with surface features, Aerial photo and satellite imagery, Photo and image interpretation.

UNIT III

Types and capabilities of GIS, Advantages of GIS over conventional methods.

UNIT IV

Importance of ground truth establishment, Capabilities of GIS for spatial decision

support system, Use of GIS and remote sensing for land and water resources data collection, analysis and interpretation,

UNIT V

Application of GIS in water and land resource development and management, irrigation planning, reservoir studies

UNIT VI

Soil moisture detection uses RS, monitoring and evaluation of command area using RS and GIS techniques, assessment and mapping of waterlogged and salinity area, evapotranspiration study and yield prediction using RS, performance study of command area, ground water investigation using RS and GIS techniques.

Practical:

Familiarization with remote sensing and GIS hardware, software and their principle of working, Methods of establishing ground truth, Comparison between ground truth and remotely sensed data, case studies using GIS and RS for soil moisture detection , monitoring and evaluation of command area , assessment and mapping of waterlogged and salinity area, evapotranspiration, yield prediction study , performance study of command area, ground water investigation .

Suggested Books:

- De Mess MN. 2004. Fundamental of Geographic Information System. John Wiley & Sons.
Lille Sand T & Kaiffer R.1987. Remote Sensing and Image Interpretation. John Wiley & Sons.
Sabbins F.1987. Remote Sensing Principle and Interpretation. Freeman
Burrough and McDonnell, Principles of GIS. Oxford university Press
Lillesand T., Kiefer R.W., Chipman J.W. Remote Sensing and Image Interpretation John Wiley & Sons.
Joseph George, Fundamentals of Remote Sensing second edition, Universities Press.
Kang tsung Chang. Introduction to Geographic Information System. Tata Mcgraw Hill
RRSSC, Nagpur, Training notes of application of Remote Sensing and GIS for natural resources.

IDE-610	Risk Management in Water Resources	3(2+1)
----------------	---	---------------

Theory:

UNIT I

Risk, hazard, vulnerability, probability: definition, concept, interrelationships, methods and tools, uncertainty, sources of uncertainty, methods and tools for estimation of uncertainty

UNIT II

Understanding risk, risk management, issues and challenges involved in risk management

UNIT III

Risk management: irrigation, water resources, watershed, water distribution, draught

UNIT IV

Multi criteria analysis: composite and compromise programming, Analytical hierarchical process (AHP), fuzzy risk, aggregative risk analysis, spatial and temporal risks, reliability analysis

Practical:

Assessment of hazards, vulnerability and risk
Examples of multi criteria analysis
Examples of AHP
Examples of composite and compromise programming
Examples of fuzzy risk
Risk management case studies: Irrigation
Risk management case studies: rainfed agriculture
Risk management case studies: draught
Risk management case studies: watershed development

Suggested Books

Simon Pollard. 2008. Risk Management for Water and Wastewater Utilities. IWA
Vairavamoorthy, K., S. D. Gorantiwar, J. Yan, H. M. Galgale, M. A. M. Mansoor and S.Mohan. 2006. Water Safety Plans: Risk Assessment for Contaminant Intrusion into Water Distribution Systems. Water Engineering Development Center, UK, ISBN No. 1 84380 102 7.
Lumbroso, D., S.D. Gorantiwar, D. Nichols, E. Penning-Rowell, S. Surendran and H. Stolk. 2007. Risk assessment for flood incident management: Framework and tools. Science Report: SC050028/SR1. Environment Agency, Rio House, Waterside Drive, Aztec West, Almondsbury, Bristol, BS32 4UD .
Gorantiwar, S.D. and I.K.Smout. 2007. Risk assessment for flood incident management Risks and consequences of failure of reactive mitigation measures. Science Report – SC050028/SR4. Environment Agency, Rio House, Waterside Drive, Aztec West, Almondsbury, Bristol, BS32 4UD. Pollard, S. 2007. Risk management for the water utility sector. London, UK, IWA Publishing. (Water and wastewater process technologies series) - ISBN: 1843391376

IDE 611

Water Resource Economics and Auditing

3(2+1)

Theory:

UNIT I

An array of decision types, supply enhancement and demand management, economics, environment and equity, optimal allocation and development

UNIT II

Costs of water supply, efficiency for a single water using agent, economic efficiency

opportunity costs.

UNIT III

Policy background, required economic analysis, a project analysis example, financing projects, cost allocation by separate costs.

UNIT IV

The instrument of water marketing, basic water trade and value trade and value theory, ground water challenge

UNIT V

The term of pricing, the customary objectives of rate setting, the economic theory of pricing, specific seasonal volumetric rates

UNIT VI

Water auditing: Availability of water in the reservoirs, season wise water use for irrigation, water use for non-irrigation purpose against projected use

Practical:

Supply enhancement and demand management, economics, environment and equity, optimal allocation and development costs of water supply, efficiency for a single water using agent, economic efficiency opportunity costs, financing projects, basic water trade and value trade and value theory, the term of pricing, the customary objectives of rate setting, the economic theory of pricing

Suggested Books:

Water Resource Economics. 2006. Ronald C. Griffin. The MIT press.

Report on Water Audit of Irrigation Projects in Maharashtra 2004-05. 2006. Water Resources Department. Govt. of Maharashtra.

IDE 693

Special Problem

1 (0+1)

Special Problem related to any topic in Irrigation and Drainage Engineering. A report on the study to be submitted for evaluation.

IDE 694

Case Study

1 (0+1)

Case study on any topic from Irrigation and Drainage Engineering selected in consultation with Research Guide. The case study report to be submitted for evaluation.

B) Minor Subjects

AE 601	Environmental Impact Assessment	3(1+2)
--------	---------------------------------	--------

Theory:

UNIT I

Introduction: terminology, environment and sustainability, classification of the environment, livelihoods and natural resources, EIA concepts, nature of EIA, diffusion and evolution of EIA, the Government of India's directives on EIA, environmental policy and institutional framework in India, legal basis for EIA in India, Law on Ecological Expert Evaluation and the Evaluation of Impact on the Environment.

UNIT II

Environmental impact assessment process

Planning and Management of Impact Studies: conceptual approach for environmental impact studies, proposal development, interdisciplinary team formation, team leader selection and duties, general study management, fiscal control.

Simple Methods for Impact Identification – Matrices, Networks, and Checklists: background information, interaction-matrix methodologies, network methodologies, checklist methodologies

Description of Environmental Setting (Affected Environment): conceptual framework, initial list of factors, selection process, documentation of selection process, data sources, special issues and concerns.

Environmental Indices and Indicators for Describing the Affected Environment: background information, environmental-media indices (air quality, water quality, noise, ecological sensitivity and diversity, archeological resources, visual quality, quality of life), development of indices.

UNIT III

Public Participation in Environmental Decision Making: definitions, regulatory requirements, advantages and disadvantages of public participation, public participation in the environment impact assessment process, objectives of public participation, identification of publics, selection of public participation techniques, techniques for conflict management and dispute resolution, practical considerations for public participation program implementation, incorporation of results in decision making,

UNIT IV

Preparation of Written Documentation: initial planning phase, detailed planning phase, writing phase.

Practical:

Prediction and Assessment of Impacts on the Surface-Water Environment: basic information on surface-water quantity and quality, legislation and regulations (national and international), conceptual approach for addressing surface-water-environment impacts (identification of surface-water quantity or quality impacts, description of existing surface-water resource

conditions, procurement of relevant surface-water quantity-quality standards, impact predictions, assessment of impact significance, identification and incorporation of mitigation measures), case study

Prediction and Assessment of Impacts on the Soil and Groundwater Environments: background information on the soil environment, background information on groundwater quantity and quality, legislation and regulations (national and international), conceptual approach for addressing soil- and groundwater-environment impacts (identification of soil and / or groundwater quantity-quality impacts, description of existing soil and / or groundwater resources, procurement of relevant soil and / or groundwater quantity-quality standards, impact prediction, assessment of impact significance, identification and incorporation of mitigation measures), case study

EIA of irrigation projects

EIA of watershed development projects

EIA of drainage projects

Suggested Books:

- Jain, R.K., et al. 2001. Environmental Assessment. Second Edition. McGraw-Hill Professional Publishing.
- Canter, Larry W. 1996. Environmental Impact Assessment. Second Edition. McGraw-Hill Inc. Series in Water Resources & Environmental Engineering.
- Environmental Science for Environmental Management. 2000. Edited by Timothy O'Riordan. Second Edition. Prentice Hall. Pearson Education Limited.
- Glasson, John. 1999. Introduction to Environmental Impact Assessment: Principles and Procedures, Process, Practice, and Prospects. UCL Press.
- Wood, Christopher. 1995. Environmental Impact Assessment / A Comparative Review. Prentice Hall. Pearson Education Limited.
- Calow, Peter. 1999. Handbook of Environmental Impact Assessment. Blackwell Science
- Westman, Walter E. 1985. Ecology, Impact Assessment, and Environmental Planning. Wiley-Interscience.
- Gilpin, Alan. 1995. Environmental impact assessment (EIA): cutting edge for the twenty-first century, Cambridge University Press.

AE 602

Climate Change Impact, Adaptation and Mitigation

3(2+1)

Theory:

UNIT I

Understanding of climate science

An Introduction to Climate Change: The Science behind the Phenomenon, What is Climate Change, Impacts of a changing climate, The link between the science, the effects and business, Key economic impact issues, Vulnerability and coping with impacts

UNIT II

Policy and Regulation, UNFCCC: Outline of the treaty, The Kyoto Protocol, 'Post 2012'

and the Bali Roadmap', Other treaties

UNIT III

Carbon Finance; An Introduction to the Flexible Mechanisms: Emissions trading. The Flexible Mechanisms of the Kyoto Protocol: International Emission Trading (IET) and The Project-Based Mechanisms; The EU Emission Trading System: The First International Emissions; Trading Scheme in Practice: Risks and Opportunities for Participating Companies, Who loses and who gains from the EU ETS?; Market Developments in the EU ETS and the Kyoto Market: The voluntary market, The role of different countries; How financial institutions can encounter the challenges related to climate change and emissions trading

UNIT IV

Climate change models

UNIT V

Understanding the concept of Integrated Water Resources Management in relation to Climate Change; Understanding the interaction between the climate system and the hydrological cycle; Being aware of the impacts of climate change on the natural environment and on society; Understanding of dealing with risk and uncertainty and Understanding of adaptation and mitigation in relation to water and climate change

UNIT VI

Climate change mitigation: issues and challenges, Mechanisms of climate change mitigation; methods and tools; developing scenarios, Climate change adaptation: issues and challenges, Climate change adaptation techniques, methods and tools; developing scenarios

UNIT VII

Links between climate change, water availability and agricultural production, effect of climate changes on climatological variables (rainfall, temp., humidity etc), soil moisture sea water level, water availability, agricultural production, floods, dry spells and draught. Direct and indirect impacts due to climate change.

Practical:

Impact of climate changes on agricultural production
Impact of climate changes on water availability
Impact of climate changes on rainfed agriculture
Impact of climate changes on flood
Impact of climate changes on draught
Impact of climate changes on irrigation water management
Studies on different mitigation measures
Studies on different adaptation measures

Suggested Books:

Intergovernmental Panel on Climate Change. 1996. Climate Change 1995: Impacts, Adaptations, and Mitigation: Contribution of Working Group II to the Second Assessment Report, Cambridge University Press.

Frederick, K. D., D. C. Major, and E. Z. Stakhiv, eds. 1997, Climate Change and Water Resources Planning Criteria, Kluwer Academic Publishers, Dordrecht, The Netherlands.

James J. McCarthy. 2001. Climate change 2001: impacts, adaptation, and vulnerability. Cambridge University Press.

B Smit, O Pilifosova, I Burton, B Challenger, S. 2001. Adaptation to climate change in the context of sustainable development and equity. Cambridge University Press

Bert Metz. 2007. Climate Change 2007. Cambridge University Press.

IPCC Reports

AE 603	Research Techniques	3(2+1)
---------------	----------------------------	---------------

Theory:**UNIT I**

Basic concept of principal component analysis, Geometrical properties of principal components, Decomposition properties of principal components, Rotation of principal components, Use of principal components in regression analysis and cluster analysis, Use principal components to detect outlying and influential observations.

UNIT II

Dimensional homogeneity, Buckingham pi theorem, Model and Prototype Similarity Linear, Areal, kinematic and dynamic similarity.

UNIT III

Measuring systems and control of measuring instruments. Sensors and Transducers, Various sensors available for pressure measurement / load measurement / strain measurement/ moisture measurement, etc.

UNIT IV

Basic research, applied research and development, Administration of research. PERT and CPM for management of Research

Practical:

Numerical on dimensional homogeneity, Numerical on Buckingham Pi theorem

Study of sensors for pressure, strain, moisture measurement.

Numerical on PERT and CPM.

Hands on for Computer software for Principal Component Analysis.

Suggested Books:

Huntley, H.E. 1974. Dimensional Analysis. Dover Publ.

Riggs, J. L., L. L. Bethel, F. S. Atwater, G.H.E. Smith, H. A. Stackman Jr. 1979. Industrial Organization and Management. McGraw-Hill, Kogakusha, Tokyo.

Sharma, S. D. 1999. Operations Research. Kedar Nath-RamNath and Co. Publishers, Meerut.

Sawhney AK. 2008. Electrical and Electronics Measurement and Instrumentation. Dhanpat Rai & Sons.

Jolliffe, I.T. 1986. Principal Component Analysis. Springer-Verlag, New York.

Dunteman, George H. 1989. Principal Component Analysis. SAGE Publication India Pvt. Ltd. New Delhi-110 048.

AE 604	Bench Marking and Performance Analysis	3(2+1)
---------------	---	---------------

Theory:

UNIT I

What is benchmarking? Why is benchmarking needed? , What is The Benchmarking Process? Recognising the Need for Benchmarking, What should be benchmarked?, Who does the benchmarking? What are the benefits of benchmarking? What extra tasks and costs does benchmarking involve? What is the relationship between benchmarking and performance assessment? Different sectors that need benchmarking with emphasis on the project in water and environmental sectors.

UNIT II

Benchmarking theory, Scoping Benchmarking Activity

Data requirement, capture and gathering

Types of Benchmarking, How to conduct a study, Benchmarking methods

Rapid Appraisal Process (RAP), Explanation and Tools, External and internal indicators

UNIT III

Analysing and identifying best practices, Identifying best utilities/companies/projects, Competencies and Competition, Objective Analysis of Service Delivery, Reviewing performance, identifying gaps in performance, Developing performance improvements, Implementing and monitoring progress on performance structures., Preparation and presentation of action plans, programme implementation

UNIT IV

Performance, their measures: productivity, equity, adequacy, reliability, flexibility, sustainability, efficiency etc, characteristics of performance measures, types: allocative type, scheduling type, different phases of performance measures: planning, operation and evaluation, spatial and temporal variation of performance measures, indicators of different performance measures

Practical:

- Benchmarking of irrigation projects
- Benchmarking of watershed projects
- Performance evaluation of irrigation project
- Performance evaluation of watershed projects
- Case studies on benchmarking and performance evaluation

Suggested Books:

IPTRID. August 2001. Guidelines for benchmarking performance in the irrigation and drainage sector, by Malano, H. & Burton, M. IPTRID Knowledge Synthesis Report No. 5. FAO. Rome.

Mark. T. Czarnecki. Benchmarking Strategies for Health Care Management. Aspen Publishers, Inc.

Gorantiwar, S.D. and I.K.Smout. 2005. Performance assessment of irrigation water management of heterogeneous irrigation schemes. Irrigation and Drainage Systems, 19:1-60.

Charles Burt. 2001. Rapid Appraisal Process (RAP) and Benchmarking Explanation and Tools. FAO.

Hector Malano and Martin Burton. 2001. Guidelines for benchmarking performance in the irrigation and drainage sector. FAO.

Sanford Berg.2009. Water Utility Benchmarking. IWA Publishing.

SWCE 605	Hydrological Models	3(2+1)
-----------------	----------------------------	---------------

Theory:**UNIT I**

The role of hydrology models: Objectives and concepts. Types of models. Model components.

Modelling procedures: problem definition, boundary identification, data requirements, calibration and validation.

Designing a conceptual model

Rainfall-runoff models: conceptual models, unit hydrograph models, mechanistic catchment models.

Sensitivity analysis, parameterisation, calibration, validation, and evaluation.

Stanford Watershed model

UNIT II

HEC-RAS (Hydrologic Engineering Center- River Analysis System) model

UNIT III

HEC-HMS (hydrologic Engineering Center- Hydrologic Modelling System) model

UNIT IV

HEC-WMS (hydrologic Engineering Center- Watershed Modelling System) model

UNIT V

TR-20 (Technical Release No. 20) model- Computer Program for Project Formulation Hydrology

UNIT VI

MODFLOW (USGS Modular Three-Dimensional Groundwater Flow Model)

UNIT VII

Watershed Hydrologic and Water Quality Modeling- HSPF(Hydrologic Simulation

Program Fortran) model for simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants

Practical:

Exercises with case studies for validation, calibration and use of HEC-RAS model for water resources and hydrology

Exercises with case studies for validation, calibration and use of HEC-HMS model for water resources and hydrology

Exercises with case studies for validation, calibration and use of HEC-WMS model for water resources and hydrology

Exercises with case studies for validation, calibration and use of TR20 model for water resources and hydrology

Exercises with case studies for validation, calibration and use of MODFLOW model for water resources and hydrology

Exercises with case studies for validation, calibration and use of HSPF model for water resources and hydrology

Suggested Books:

Vijay P. Singh and Donald K. Frevert. 2005. Watershed Models. CRC Press, Taylor and Francis Group

Technical document and user manual of HEC-RAS

Technical document and user manual of HEC-HMS

Technical document and user manual of HEC-WMS

Technical document and user manual of TR20

Technical document and user manual of MODFLOW

Technical document and user manual of HSPF

C) Supporting Subjects

BSCT 601	Object Oriented Programming	3(2+1)
-----------------	------------------------------------	---------------

Theory:

UNIT I

Introduction to Computer Systems, Hardware and Software; Computing Environments- Personal, Time sharing and Client Server Computing.

UNIT II

Types of programming languages. Software Development Process Models. Differentiation between Procedural and Object Oriented approach;

UNIT III

Programming Language: Object oriented approach Using C++, Data Abstraction and Classes, Class Constructors and Destructors. Working with Classes- friends, Operator overloading;

UNIT IV

Automatic Conversions and type casts for classes, Dynamic memory and classes. Class Inheritance- An Array base Class, Deriving a class, Virtual Function, Classes with member classes, multiple Inheritance,

UNIT V

Output and Files- Overview of C++ Input and Output, Output with cout, Input with cin, file Input and output

Practical:

Study of Programming Language: Object oriented approach Using C++, Data Abstraction and Classes, Class Constructors and Destructors. Study of Automatic Conversions and type casts for classes, Dynamic memory and classes. Study of Output and Files- Overview of C++ Input and Output, Output with cout, Input with cin, file Input and output.

Suggested Books:

C++ Primer plus, Stephen Prata, Galgotia publications

Object Oriented Programming with C++, E. Balguruswamy, Tata Mc-Graw Hill Publications Ltd. New Delhi.

Software Engineering, Ian Sommerville, Pearson education Asia

MATH 601	Mathematical Modelling and Software Applications	3(1+2)
-----------------	---	---------------

Theory:

UNIT I

Introduction, stages in mathematical modeling, importance of mathematical modeling.

UNIT II

Classification of mathematical models: Continuous and discrete models, linear models and its applications, quadratic models and its applications, exponential models and its applications, empirical models and its applications.

UNIT III

Introduction to MAT LAB, Desktop tools

UNIT IV

MAT LAB basics: variables and arrays, Initialization variables, Matrix manipulation, linear algebra, roots of polynomials, data analysis and statistics. Solution of the mathematical problems using MAT LAB and MAT LAB tools. Graph plotting: 2-D, 3-D, Contour.

UNIT V

Simulation of mathematical models using MAT LAB programming.

Practical:

Hands on for UNIT III, IV and V.

Suggested Books:

Dym, Clive L. Principles of Mathematical modeling.

Chapman, Stephen J. MAT LAB programming for Engineers.

STAT 609**Operations Research****3(2+1)****Theory:**

UNIT I

Definition and scope of operations research. Management applications of operations research. Main characteristics of operations research

UNIT II

Linear programming, LP models, formulation of problems, limitations, simplex method, complications and their resolution, duality principle, application of LP

UNIT III

Transportation type problems, formulation, basic concepts, finding initial basis, feasible and optimal solutions, degeneracy, Transportation Problem with minimum time requirements, the unbalanced Transportation Problem. Assignment problem: formulation and solution.

UNIT IV

Dynamic programming: multistage problems, recursive equation approach.

UNIT V

Inventory control, economic lot size model, production planning, single and multi-period models.

UNIT VI

Replacement problems: models: basic concepts, replacement of items that fail completely, replacement of equipment deteriorating with time, staffing and other problems of replacement.

UNIT VII

Queuing Theory and applications. M/M/1, M/M/s type models

Practical:

Numerical on formulation and solution of LP problems

Numerical on formulation and solution of Transportation problems

Numerical on formulation and solution of Assignment problems
Numerical on formulation and solution of DP problems
Numerical on Inventory control models
Numerical on Replacement problems
Numerical on Queuing models

Suggested Books:

Rao, S.S. 1990. Optimization- Theory and Applications.
Sharma, S.D. 1999. Operations Research. Kedar Nath Ram Nath and Co. Publishers, Meerut.
Taha, H.A. 1989. Operations Research- An Introduction. Maxwell Macmillan, New York.
Vohra, N.D. 1990. Quantitative Techniques in Management. Tata McGraw-Hill Publishing Co. New Delhi.

STAT 610	Probabilistic Approach in Design	2(2+0)
-----------------	---	---------------

Theory:

UNIT I

Review of various approaches in engineering design and introduction of probabilistic approach

UNIT II

Random variables. Probability distribution and density functions. Expected values, Mean Variance, conditional probability, characteristic functions.

UNIT III

Function of random variables. Concepts stationary, ergodic and non stationary process

UNIT IV

Auto correlation, cross correlation, covariance function power spectral and cross spectral density functions and their determination from experimental data

UNIT V

Broad band and narrow band Random process. White noise. Application in various disciplines of engineering.

Suggested Books:

Benjamin J.R., Allen, C. 1975. Probability Statistics and Decision for Civil Engineers. MGH New York.
Evan D.H. 1992. Probability and its Application for Engineers. ASQC Press and Marchel Dekkar

STAT 611	Geostatistical Analysis	2(1+1)
-----------------	--------------------------------	---------------

Theory:

UNIT I

Overview of Classical statistics, Normal and Log-normal distributions.

UNIT II

Concept of geospatial analysis and database design. Spatial statistics. Covariogram, Semivariogram and Variogram, Regularization.

UNIT III

Dispersion variance and grade- tonnage relationship. Extension variance and estimation variance

UNIT IV

Optimal valuation, kriging. Cross validation.

UNIT V

Use of data mining concepts in geospatial analysis.

Practical:

Numerical on UNIT I, II, III, IV and V.

Suggested Books

David, M. 1977. *Geostatistical ore Reserve Estimation*. Elsevier, New York.

Rendu, J. M. 1978. *An Introduction to Geostatistical Methods of Mineral Evaluation*. South African Institute of Mining and Metallurgy, Johannesburg.

D) Seminar (2 Credits)

IDE 691	Seminar I	1 (0+1)
----------------	------------------	----------------

Student will have to deliver seminar(s) on the topics related to Irrigation and Drainage Engineering.

IDE 692	Seminar II	1 (0+1)
----------------	-------------------	----------------

Student will have to deliver seminar(s) on the topics related to Irrigation and Drainage Engineering.

E) Doctoral Research (45 Credits)

IDE 699	Doctoral Research	45 (0+45)
----------------	--------------------------	------------------

F) Non Credit Compulsory Courses (Optional*)

PGS-501

Library and Information Services.

1(0+1)

Practical:

Introduction to library and its services; Role of libraries in education, research and technology transfer; Classification systems and organization of library; Sources of information- Primary Sources, Secondary Sources and Tertiary Sources; Intricacies of abstracting and indexing services (Science Citation Index, Biological Abstracts, Chemical Abstracts, CABI Abstracts, etc.); Tracing information from reference sources; Literature survey; Citation techniques/Preparation of bibliography; Use of CD-ROM Databases, Online Public Access Catalogue and other computerized library services; Use of Internet including search engines and its resources; e-resources access methods.

PGS-502

Technical Writing and Communicating Skills

1(0+1)

Practical:

Technical Writing - Various forms of scientific writings- theses, technical papers, reviews, manuals, etc; Various parts of thesis and research communications (title page, authorship contents page, preface, introduction, review of literature, material and methods, experimental results and discussion); Writing of abstracts, summaries, précis, citations etc.; commonly used abbreviations in the theses and research communications; illustrations, photographs and drawings with suitable captions; pagination, numbering of tables and illustrations; Writing of numbers and dates in scientific write-ups; Editing and proof-reading; Writing of a review article.

Communication Skills - Grammar (Tenses, parts of speech, clauses, punctuation marks); Error analysis (Common errors); Concord; Collocation; Phonetic symbols and transcription; Accentual pattern: Weak forms in connected speech: Participation in group discussion: Facing an interview; presentation of scientific papers.

Suggested Books

- Chicago Manual of Style. 14th Ed. 1996. Prentice Hall of India.
- Collins' Cobuild English Dictionary. 1995. Harper Collins.
- Gordon HM & Walter JA. 1970. Technical Writing. 3rd Ed. Holt, Rinehart & Winston.
- Hornby AS. 2000. Comp. Oxford Advanced Learner's Dictionary of Current English. 6th Ed. Oxford University Press.
- James HS. 1994. Handbook for Technical Writing. NTC Business Books.
- Joseph G. 2000. MLA Handbook for Writers of Research Papers. 5th Ed. Affiliated East-West Press.
- Mohan K. 2005. Speaking English Effectively. MacMillan India.
- Richard WS. 1969. Technical Writing. Barnes & Noble.
- Robert C. (Ed.). 2005. Spoken English: Flourish Your Language. Abhishek.

Sethi J & Dhamija PV. 2004. Course in Phonetics and Spoken English. 2nd Ed. Prentice Hall of India.

Wren PC & Martin H. 2006. High School English Grammar and Composition. S. Chand & Co.

PGS-503 Intellectual Property and Its Management in Agriculture 1(1+0)

(e- Course)

Theory:

Historical perspectives and need for the introduction of Intellectual Property Right regime; TRIPs and various provisions in TRIPS Agreement; Intellectual Property and Intellectual Property Rights (IPR), benefits of securing IPRs; Indian Legislations for the protection of various types of Intellectual Properties; Fundamentals of patents, copyrights, geographical indications, designs and layout, trade secrets and traditional knowledge, trademarks, protection of plant varieties and farmers' rights and biodiversity protection; Protectable subject matters, protection in biotechnology, protection of other biological materials, ownership and period of protection; National Biodiversity protection initiatives; Convention on Biological Diversity; International Treaty on Plant Genetic Resources for Food and Agriculture; Licensing of technologies, Material transfer agreements, Research collaboration Agreement, License Agreement.

Suggested Books:

Erbisch FH & Maredia K.1998. Intellectual Property Rights in Agricultural Biotechnology. CABI.

Ganguli P. 2001. Intellectual Property Rights: Unleashing Knowledge Economy. McGraw-Hill.

Intellectual Property Rights: Key to New Wealth Generation. 2001. NRDC & Aesthetic Technologies.

Ministry of Agriculture, Government of India. 2004. State of Indian Farmer. Vol. V. Technology Generation and IPR Issues. Academic Foundation.

Rothschild M & Scott N. (Ed.). 2003. Intellectual Property Rights in Animal Breeding and Genetics. CABI.

Saha R. (Ed.). 2006. Intellectual Property Rights in NAM and Other Developing Countries: A Compendium on Law and Policies. Daya Publ. House.

The Indian Acts - Patents Act, 1970 and amendments; Design Act, 2000; Trademarks Act, 1999; The Copyright Act, 1957 and amendments; Layout Design Act, 2000; PPV and FR Act 2001, and Rules 2003; National Biological Diversity Act, 20

PGS-504

Basic Concepts in Laboratory Techniques

1(0+1)

Practical:

Safety measures while in Lab; Handling of chemical substances; Use of burettes, pipettes, measuring cylinders, flasks, separatory funnel, condensers, micropipettes and vascupets; washing, drying and sterilization of glassware; Drying of solvents/chemicals. Weighing and preparation of solutions of different strengths and their dilution; Handling techniques of solutions; Preparation of different agro-chemical doses in field and pot applications; Preparation of solutions of acids; Neutralisation of acid and bases; Preparation of buffers of different strengths and pH values. Use and handling of microscope, laminar flow, vacuum pumps, viscometer, thermometer, magnetic stirrer, micro-ovens, incubators, sandbath, waterbath, oilbath; Electric wiring and earthing. Preparation of media and methods of sterilization; Seed viability testing, testing of pollen viability; Tissue culture of crop plants; Description of flowering plants in botanical terms in relation to taxonomy

Suggested Books

Furr AK. 2000. CRC Hand Book of Laboratory Safety. CRC Press.
Gabb MH & Latchem WE. 1968. A Handbook of Laboratory Solutions.
Chemical Publ. Co.

PGS-505

**Agricultural Research, Research Ethics and Rural
Development Programmes**

1(1+0)

(e-Course)

Theory:

UNIT I

History of agriculture in brief; Global agricultural research system: need, scope, opportunities; Role in promoting food security, reducing poverty and protecting the environment; National Agricultural Research Systems (NARS) and Regional Agricultural Research Institutions; Consultative Group on International Agricultural Research (CGIAR): International Agricultural Research Centres (IARC), partnership with NARS, role as a partner in the global agricultural research system, strengthening capacities at national and regional levels; International fellowships for scientific mobility.

UNIT II

Research ethics: research integrity, research safety in laboratories, welfare of animals used in research, computer ethics, standards and problems in research ethics.

UNIT III

Concept and connotations of rural development, rural development policies and strategies. Rural development programmes: Community Development Programme, Intensive Agricultural District Programme, Special group – Area Specific Programme, Integrated Rural Development Programme (IRDP) Panchayati Raj Institutions, Co-operatives, Voluntary Agencies/Non-Governmental Organisations. Critical evaluation of rural development policies and programmes. Constraints in implementation of rural policies and programmes.

UNIT IV

Optimal valuation, kriging. Cross validation.

UNIT V

Use of data mining concepts in geospatial analysis.

Suggested Books:

- Bhalla GS & Singh G. 2001. Indian Agriculture - Four Decades of Development. Sage Publ.
- Punia MS. Manual on International Research and Research Ethics. CCS, Haryana Agricultural University, Hisar.
- Rao BSV. 2007. Rural Development Strategies and Role of Institutions - Issues, Innovations and Initiatives. Mittal Publ.
- Singh K.. 1998. Rural Development - Principles, Policies and Management. Sage Publ.

PGS-506**Disaster Management****1(1+0)****(e-Course)****Theory:**

UNIT I

Natural Disasters- Meaning and nature of natural disasters, their types and effects. Floods, Drought, Cyclone, Earthquakes, Landslides, Avalanches, Volcanic eruptions, Heat and cold Waves, Climatic Change: Global warming, Sea Level rise, Ozone Depletion

UNIT II

Man Made Disasters- Nuclear disasters, chemical disasters, biological disasters, building fire, coal fire, forest fire. Oil fire, air pollution, water pollution, deforestation, Industrial wastewater pollution, road accidents, rail accidents, air accidents, sea accidents.

UNIT III

Disaster Management- Efforts to mitigate natural disasters at national and global levels. International Strategy for Disaster reduction. Concept of disaster management, national disaster management framework; financial arrangements; role of NGOs, Community-based organizations, and media. Central, State, District and local Administration; Armed forces in Disaster response; Disaster response: Police and other organizations.

Suggested Books:

- Gupta HK. 2003. Disaster Management. Indian National Science Academy. Orient Blackswan.
- Hodgkinson PE & Stewart M. 1991. Coping with Catastrophe: A Handbook of Disaster Management. Routledge.
- Sharma VK. 2001. Disaster Management. National Centre for Disaster Management, India.