

Department of Civil Engineering, IIT Delhi

Master of Technology in Water Resources Engineering

As on 22/02/2015

Proposed Credit Structure

Category	PC		PE	OC	Total
Credits	39		15	0	54
	Major Project:	Others:			
	18	21			

Semester-wise Distribution of Core and Elective Courses

Sem	Courses (Abbreviated Title, L-T-P, credits)						Lecture courses	L	T	P	Total	Credits
I	Hyd. Processes (3-0-0) 3	Opt. Tech (3-0-0) 3	GW Hyd (3-0-0) 3	Stochastic Hyd. (2-0-2) 3	PE 1 (3-0-0) 3		5	14	0	2	16	15
II	Adv Hydraulics (3-0-0) 3	Finite Element (3-0-0) 3	Sim. Lab I (0-0-3) 1.5	Sim. Lab II (0-0-3) 1.5	PE 2 (3-0-0) 3	PE 3 (3-0-0) 3	4	12	0	6	18	15
Summer	CED Major Project Part I (CEW)											0
III	CED Major Project Part I (0-0-12) 6			PE 4 (3-0-0) 3	PE 5 (3-0-0) 3		2	6	0	12	18	12
IV	CED Major Project Part II (0-0-24) 12						0	0	0	24	24	12

List of Proposed Core and Elective Courses

Programme Core (PC)

Major Project Part I	0-0-12	6
Major Project Part II	0-0-24	12
Hydrologic Processes and Modeling	3-0-0	3
Optimization Techniques in WR	3-0-0	3
Advanced Hydraulics	3-0-0	3
Groundwater Hydrology	3-0-0	3
Finite Element in Water Resources	3-0-0	3
Stochastic Hydrology	2-0-2	3

Simulation Laboratory-I	0-0-3	1.5
Simulation Laboratory-II	0-0-3	1.5
Total Credits		39

Programme Electives (PE)

Environmental Dynamics and Management	3-0-0	3
Economic Aspects of Water Resources Development	3-0-0	3
Groundwater Flow and Pollution Modeling	3-0-0	3
Surface Water Quality Modeling and Control	3-0-0	3
Hydroelectric Engineering	3-0-0	3
Geographic Information Systems	2-0-2	3
Hydrologic Applications of Remote Sensing	2-0-2	3
Water Resources Systems	3-0-0	3
Urban Water Infrastructure	3-0-0	3
Soft Computing Techniques in Water Resources	2-0-2	3
Mechanics of Sediment Transport	2-0-2	3
Eco-hydraulics and Hydrology	3-0-0	3
Advanced Hydrologic Land Surface Processes	3-0-0	3
Minor Project	0-0-6	3
Independent Study (CEW)	0-3-0	3
Total credits (Required)		15

Master of Technology in Water Resources Engineering

List of Proposed Core and Elective Courses

Programme Core (PC)

Major Project Part I	0-0-12	6	CVD831
Major Project Part II	0-0-24	12	CVD832
Hydrologic Processes and Modeling	3-0-0	3	CVL730
Optimization Techniques in WR	3-0-0	3	CVL731
Groundwater Hydrology	3-0-0	3	CVL732
Stochastic Hydrology	2-0-2	3	CVL733
Advanced Hydraulics	3-0-0	3	CVL734
Finite Element in Water Resources	3-0-0	3	CVL735
Simulation Laboratory-I	0-0-3	1.5	CVP730
Simulation Laboratory-II	0-0-3	1.5	CVP731
Total Credits		39	

Programme Elective (PE)

Soft Computing Techniques in Water Resources	2-0-2	3	CVL736
Environmental Dynamics and Management	3-0-0	3	CVL737
Economic Aspects of Water Resources Development	3-0-0	3	CVL738
Groundwater Flow and Pollution Modeling	3-0-0	3	CVL830
Surface Water Quality Modeling and Control	3-0-0	3	CVL831
Hydroelectric Engineering	3-0-0	3	CVL832
Water Resources Systems	3-0-0	3	CVL833
Urban Water Infrastructure	3-0-0	3	CVL834
Eco-hydraulics and Hydrology	3-0-0	3	CVL835
Advanced Hydrologic Land Surface Processes	3-0-0	3	CVL836
Mechanics of Sediment Transport	2-0-2	3	CVL837
Geographic Information Systems	2-0-2	3	CVL838
Hydrologic Applications of Remote Sensing	2-0-2	3	CVL839
Minor Project	0-0-6	3	CVS730
Independent Study (CEW)	0-3-0	3	CVS830
Total credits (Required)		15	

COURSE TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	HYDROLOGICAL PROCESSES AND MODELLING
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL730
6.	Status (<i>category for program</i>)	PROGRAMME CORE

7.	Pre-requisites (course no./title)	Nil
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	NIL
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	CEL 735

9.	Not allowed for (indicate program names)	
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10.	Frequency of offering	☐ Every sem ☒ 1 st sem ☐ 2 nd sem ☐ Either sem
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11.	Faculty who will teach the course R. KHOSA, A.K. GOSAIN, C.T. DHANYA AND OTHER WRE FACULTY	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): 1. To develop a consistent understanding of hydrological Land-Surface Processes. 2. To develop rational theoretical and physically rigorous formulations of individual component processes of the hydrologic cycle. 3. To develop alternative modelling approaches of the hydrologic system	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Hydrologic Cycle and its individual component processes. River Basin as a Linear Hydrologic System. Linear Theory of Hydrologic Systems. Lumped Integral and Distributed Differential modelling approaches. Transform methods of Linear Systems Analysis. Morphological attributes of watersheds and its role in runoff dynamics. Flood Routing by Lumped Hydrologic and Distributed Hydraulic approaches. Unsaturated zone Hydrology and physics of the Soil-	
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	Plant-Atmosphere Continuum. Calibration and Validation of Rainfall-Runoff models.
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15. Lecture Outline (*with topics and number of lectures*)

Module no.	Topic	No. of hours
1	Watershed as a System, watershed and drainage network morphology	3
2	Hydrologic unit as Linear Parametric systems, their identification and response simulation via convolution	6
3	Flood movement in channels, reservoirs and catchments, hydrologic and hydraulic approaches to flood routing	6
4	Kinematic, Diffusion and complete dynamic wave models and solution techniques using Finite Differences and Method of Characteristics	6
5	Soil and Water interaction; soil moisture movement in the Unsaturated Zone and models of Infiltration	8
6	Hydrology of small catchments and modelling overland flow	4
7	Evaporation, Evapotranspiration and Soil-Plant-Atmosphere Continuum	5
8	Interception	2
9	Calibration and Validation of Rainfall-Runoff models	2
10		
11		
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		NIL

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

1. Chow, V. T., Maidment, D. R., and Mays, L. W., *Applied Hydrology*, Tata McGraw-Hill, 1988.
2. Ponce, V. M., *Engineering hydrology: Principles and practices*, Prentice Hall, 1989.
3. Singh, V. P., *Elementary hydrology*, Pearson College Division, 1992.
4. Subramanya, K., *Engineering hydrology*, Tata McGraw-Hill Education, 1994.
5. Eagleson, P. S., *Dynamic hydrology*, 1970.
6. Monteith, J., and Unsworth, M., *Principles of Environmental Physics*, Academic Press,

2007.

7. Guymon, G. L., Unsaturated zone hydrology, Pearson Education, 1994.
8. Tindall, J. A., Kunkel, J. R., and Anderson, D. E., Unsaturated zone hydrology for scientists and engineers, Upper Saddle River, NJ: Prentice Hall, 1999.
9. Dooge, J., and O'Kane, P., Deterministic Methods in Systems Hydrology: IHE Delft Lecture Note Series, CRC Press, 2003.
10. Ojha, C., Berndtsson, R., and Bhunya, P., Engineering hydrology, Oxford University Press, 2008.
11. Allen, R. G., Pereira, L. S., Raes, D., and Smith, M., Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. FAO, Rome, 300(9), 1998.
12. Black, P. E., Watershed hydrology, John Wiley & Sons, Inc., 1991.
13. Hillel, D., Soil and water: physical principles and processes, Elsevier, 2012.
14. Dooge, J., Linear theory of hydrologic systems. No. 1468, Agricultural Research Service, US Department of Agriculture, 1973.
15. Singh, V. P., Hydrologic systems. v. 1. Rainfall-runoff modeling, 1988.
16. Hillel, D., Introduction to environmental soil physics, Academic press, 2003.
17. Viessman, W., Harbaugh, T. E., and Knapp, J., Introduction to hydrology, Intex Educational, 1972.
18. Radcliffe, D. E., and Šimůnek, J., Soil physics with HYDRUS: modeling and applications, Boca Raton, FL: CRC press, 2010.

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	YES
19.2	Hardware	YES
19.3	Teaching aides (videos, etc.)	Yes
19.4	Laboratory	NO
19.5	Equipment	NO
19.6	Classroom infrastructure	Yes
19.7	Site visits	No

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	20-40
20.2	Open-ended problems	20-40
20.3	Project-type activity	10-30
20.4	Open-ended laboratory work	NIL
20.5	Others (please specify)	10-20 (REVIEW OF PAPERS; TERM PAPERS etc.)

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	Civil Engineering
2.	Course Title (<i>< 45 characters</i>)	SIMULATION LABORATORY I
3.	L-T-P structure	0 - 0 - 3
4.	Credits	1.5
5.	Course number	CVP730
6.	Status (<i>category for program</i>)	PROGRAMME CORE

7.	Pre-requisites (course no./title)	Nil
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	NIL
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	CEP740

9.	Not allowed for (indicate program names)	Nil
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course All WRE faculty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): 1. To simulation water resources system using differential equations. 2. The main course objective is to develop skills in subroutine to solve the various complex water resources problems.	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Basic of Fortran 90, Fortran 95 and computing, Numerical solution of different types of partial differential equations: parabolic equation, elliptical equation, hyperbolic equation, Backwater curve analysis; Groundwater flow problems, Pipe network analysis, Unsteady channel flow.	
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15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	NA	NA
2	NA	NA
3	NA	NA
4	NA	NA
5	NA	NA
6	NA	NA
7	NA	NA
8	NA	NA
9	NA	NA
10	NA	NA
11	NA	NA
12	NA	NA
COURSE TOTAL (14 times 'L')		NA

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Basic of Fortran 90, Fortran 95	9
2	Basics of computing	3
3	Numerical solution of different types of partial differential equations	6
4	Parabolic equation	3
5	Elliptical equation	3
6	Hyperbolic equation	3
7	Backwater curve analysis	3
8	Groundwater flow problems	6
9	Pipe network analysis	3
10	Unsteady channel flow	3
COURSE TOTAL (14 times 'P')		42

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

- 1) Chow, V.T., Open Channel Hydraulics, McGraw-Hill, 2010.
- (2) Rajaraman, V., Computer Programming in Fortran 90/95, Prentice-Hall of India, 1997.
- (3) Singh, V.P., Elementary Hydrology, Prentice-Hall of India, 1994.
- (4) Jain, M.K., and Iyengar, S.R.K., and Jain, R.K., Computational Methods for Partial Differential Equations, New Age International (P) Limited, 2002.
- (5) Chapman, S. J., Introduction to Fortran 90/95, McGraw-Hill, 1999

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	Yes
19.2	Hardware	No
19.3	Teaching aides (videos, etc.)	No
19.4	Laboratory	Existing
19.5	Equipment	Existing
19.6	Classroom infrastructure	Yes
19.7	Site visits	No

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	0
20.2	Open-ended problems	Upto 10
20.3	Project-type activity	Nil
20.4	Open-ended laboratory work	Upto 20
20.5	Others (please specify)	Upto 70 (Water resources related problems)

Date: 10-03-2015

(Signature of the Head of the Department)

MINOR PROJECT TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	MINOR PROJECT
3.	L-T-P structure	0 - 0 - 6
4.	Credits	3
5.	Course number	CVS730
6.	Status (<i>category for program</i>)	PROGRAMME ELECTIVE

7.	Pre-requisites (course no./title)	NONE
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8.	Supersedes any existing course	NONE
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9.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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10.	FACULTY WHO WILL SUPERVISE PROJECT STUDY ALL WATER RESOURCES FACULTY	
11.	Will the PROJECT SUPERVISION require any visiting faculty?	MAY BE INVITED ON REQUEST BY FACULTY SUPERVISOR/STUDENT

12.	PROJECT objective (<i>about 50 words</i>): (1) TO EXPLORE A PRESCRIBED PROBLEM BASED ON LABORATORY AND/OR NUMERICAL MODELLING BASED APPROACHES (2) TO EXPLORE DESIGN METHODOLOGIES IN THE AREA OF WATER RESOURCES ENGINEERING	
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13. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	SPECIFIC TO THE PROBLEM TAKEN UP FOR THE STUDY	OPEN

14. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

RELEVANT, CONTEXTUAL RESEARCH ARTICLES, REPORTS AND BOOKS

15. Resources required for the STUDY *(itemized & student access requirements, if any)*

19.1	Software	YES
19.2	Hardware	YES
19.3	PRESENTATION aides (videos, etc.)	YES
19.4	Laboratory	YES
19.5	Equipment	YES
19.6	Classroom infrastructure	NO
19.7	Site visits	MAY BE REQUIRED AS PART OF THE STUDY

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	Civil Engineering
2.	Course Title (<i>< 45 characters</i>)	OPTIMIZATION TECHNIQUES IN WATER RESOURCES
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL731
6.	Status (<i>category for program</i>)	PROGRAMME CORE

7.	Pre-requisites (course no./title)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	NIL
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	CEL737

9.	Not allowed for (indicate program names)	NIL
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10.	Frequency of offering	☐ Every sem ☒ 1 st sem ☐ 2 nd sem ☐ Either sem
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11.	Faculty who will teach the course Prof. A. K. Keshari, Prof. B.R. Chahar and other WRE faculty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): 1. To learn how to formulate optimization problems for real life problems 2. To know various techniques for solving optimization problems 3. To train and familiarize how to apply optimization techniques in addressing problems encountered in water resources, agriculture, environment, transportation, urban planning, civil engineering designs and other allied areas.	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Optimization techniques commonly used in water resources planning & management, water infrastructures, and irrigation and hydropower projects; Linear programming and duality, Network flow algorithms, Dynamic programming, Nonlinear programming, Geometric and Goal programming, Introduction to modern heuristic methods like genetic algorithm and simulated annealing, Multiobjective optimization, Applications and case studies in water resources, agriculture, environment and other areas of science & engineering.	
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15. Lecture Outline (*with topics and number of lectures*)

Module no.	Topic	No. of hours
1	Introduction to optimization techniques commonly used in water resources planning & management, water infrastructure, and irrigation and hydropower projects	4
2	Linear programming	5
3	Duality	2
4	Network flow algorithms	4
5	Dynamic programming	3
6	Nonlinear programming	9
7	Geometric and Goal programming	2
8	Introduction to modern heuristic methods like genetic algorithm and simulated annealing	3
9	Multiobjective optimization	2
10	Applications and Case Studies in water resources, agriculture and environment	5
11	Applications and Case Studies in other areas of science and engineering	3
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

- (1) Ravindran, A., Phillips, D. T., Solberg, J. J., *Operations Research: Principles and Practice*, 2nd Ed., John Wiley & Sons, 2007.
- (2) Rao, S. S., *Optimization: Theory and Applications*, Eastern Wiley Ltd.
- (3) Rardin, R.L., *Optimization in Operations Research*, Pearson Education, 2003.
- (3) Keshari, A.K., Datta, B., Integrated optimal management of groundwater pollution and withdrawal. *Groundwater*, 34(1): 104–113, 1996.

- (4) Keshari, A.K., and Datta, B., Multiobjective management of a contaminated aquifer for agricultural use. *Water Resources Management*, 10(5): 373-395, 1996.
- (5) Keshari, A.K. and Datta, B. A combined use of pattern search algorithms and exterior penalty function method for groundwater pollution management. *Journal of Porous Media*, 4(3): 259-270, 2001.

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	Yes (preferable)
19.2	Hardware	Yes
19.3	Teaching aides (videos, etc.)	Yes
19.4	Laboratory	No
19.5	Equipment	No
19.6	Classroom infrastructure	Yes
19.7	Site visits	No

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	60
20.2	Open-ended problems	10
20.3	Project-type activity	30
20.4	Open-ended laboratory work	0
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	Civil Engineering
2.	Course Title (<i>< 45 characters</i>)	SIMULATION LABORATORY II
3.	L-T-P structure	0 - 0 - 3
4.	Credits	1.5
5.	Course number	CVP731
6.	Status (<i>category for program</i>)	PROGRAMME CORE

7.	Pre-requisites (course no./title)	Nil
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	NIL
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	CEP740

9.	Not allowed for (indicate program names)	Nil
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course All WRE Faculty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): 1. To understand the theory of water resources software. 2. To simulate various water resources systems using softwares.	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Simulate hydraulic, hydrologic, pipe flow, water hammer using various softwares such as Visual Mod Flow, SWAT, HYDRUS, Hytran, MIKE, Bentley Software, Fluent, HMS, SAMS.	
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15. Lecture Outline (*with topics and number of lectures*)

Module no.	Topic	No. of hours
1	NA	NA
2	NA	NA
3	NA	NA
4	NA	NA
5	NA	NA
6	NA	NA
7	NA	NA
8	NA	NA
9	NA	NA
10	NA	NA
11	NA	NA
12	NA	NA
COURSE TOTAL (14 times 'L')		NA

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Bentley Software (Water Hammer, Water CAD, Water Strom etc)	6
2	Basic of MATLAB and SPSS	6
3	SWAT	3
4	Hytran	3
5	MIKE	6
6	HYDRUS	3
7	Fluent	3
8	Visual Mod Flow	6
9	HMS	3
10	SAMS	3
COURSE TOTAL (14 times 'P')		42

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

- 1) Wurbs, R. A., James W, P., Water Resources Engineering, PHI, 2014
- (2) Hirsch, C., Numerical Computation of Internal and external flows, John Wiley & Sons, 1988.
- (3) Chapra, S. C., and Canale, R. P., Numerical Methods for Engineers, 4th Ed., Tata McGraw-Hill Edition, 2002
- (4) Fitts, C. R., Groundwater Science, 2nd Ed., Elsevier, 2013.
- (5) Chanson, H., The Hydraulics of Open Channel Flow, 2nd Ed. Elsevier, 2013

Besides these manual of software be referred.

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	Yes
19.2	Hardware	No
19.3	Teaching aides (videos, etc.)	No
19.4	Laboratory	Existing
19.5	Equipment	Existing
19.6	Classroom infrastructure	Yes
19.7	Site visits	No

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	0
20.2	Open-ended problems	Upto 10
20.3	Project-type activity	0
20.4	Open-ended laboratory work	Upto 10
20.5	Others (please specify)	Upto 80 (water resources problems)

Date: 10-03-2015

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	GROUNDWATER HYDROLOGY
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL732
6.	Status (<i>category for program</i>)	PROGRAMME CORE

7.	Pre-requisites (course no./title)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	NIL
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	NIL

9.	Not allowed for (indicate program names)	
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10.	Frequency of offering	☐ Every sem ☒ 1 st sem ☐ 2 nd sem ☐ Either sem
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11.	Faculty who will teach the course All Water Resources faculty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): 1. To impart groundwater flow principles, problems and would include laws and equations that govern flow and storage of water in the subsurface zone. 2. To provides an insight into forecasting and behaviour of a regional aquifer system.	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Occurrence and movement of groundwater including subsurface investigations of groundwater. Flow through saturated and unsaturated media. well Hydraulics and aquifer parameters. Pumping wells and their design, construction, monitoring and rehabilitation of wells. Recharge of groundwater by variuos means. Salt water intrusion and coastal aquifer hydraulics. Analog and numerical models and application of Finite Difference method to groundwater, case studies.	
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15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Occurance and movement of groundwaterl,	2
2	Flow through saturated media	4
3	Flow through unsaturated media	4
4	Surface and subsurface investigation of groundwater,	4
5	Mecanics of well flow, Aquifer parameters	4
6	Pumping Tests, Design of water wells	4
7	Monitoring, construction, well development, maintainence and rehabilitation of wells	3
8	Groundwater Recharge	4
9	Saltwater Intusion and coastal aqifers	4
10	Analog and numerical models	4
11	Finite Diffrence Method in groundwater	4
12	Case studies	1
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		NIL
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		NIL

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

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|-----|--|
| (1) | Bear, J., Hydraulics of Groundwater, McGraw Hill, 1979 |
| (2) | Davis, N. S., and Roger J. M. D., Hydrogeology, John Wiley, 1966 |
| (3) | Raghunath, H. M., Groundwater, John Wiley, 1983 |
| (4) | Bouwer, H., Groundwater Hydrology, McGraw Hill, 1978 |
| (5) | Freeze R. A. and J. A. Cherry, Groundwater, Prentice Hall, 1979 |

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	yes
19.2	Hardware	yes
19.3	Teaching aides (videos, etc.)	yes
19.4	Laboratory	NA
19.5	Equipment	NA
19.6	Classroom infrastructure	yes
19.7	Site visits	

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	60
20.2	Open-ended problems	5
20.3	Project-type activity	15
20.4	Open-ended laboratory work	0
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	STOCHASTIC HYDROLOGY
3.	L-T-P structure	2 - 0 - 2
4.	Credits	3
5.	Course number	CVL733
6.	Status (<i>category for program</i>)	PROGRAMME CORE

7.	Pre-requisites (course no./title)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	NO
8.2	Overlap with any UG/PG course of other Dept./Centre	NO
8.3	Supercedes any existing course	CEL 840

9.	Not allowed for (indicate program names)	
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10.	Frequency of offering	☐ Every sem ☒ 1 st sem ☐ 2 nd sem ☐ Either sem
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11.	Faculty who will teach the course R. KHOSA, C.T. DHANYA, R. MAHESWARAN AND OTHER WRE FACULTY	
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12.	Will the course require any visiting faculty?	No
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13.	Course objective (<i>about 50 words</i>): 1. To impart knowledge of the concepts of Probability Theory in order to measure and quantify uncertainty in Stochastic Processes. 2. To explore various approaches to develop predictive models of hydrologic stochastic processes 3. To develop an understanding of the chance element in Hydrologic Processes and understanding the general theory of estimation. 4. To develop frequency models of the recurrent hydrologic extreme events and their applications to risk based hydrologic design	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Concepts of probability and Random variables; moments and expectations; Common probabilistic distributions and estimation of parameters; goodness of fit tests; Modelling of Hydrologic High and Low Extremes, Regional	
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	Frequency Analysis, Stochastic processes and modelling of stochastic time series; Markov Chains and Probabilistic Theory of Reservoir Storages
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15. Lecture Outline (*with topics and number of lectures*)

Module no.	Topic	No. of hours
1	Introduction to Uncertainty, Random Variables, Concepts of Probability, Return Period, Risk and Relevance in design	1
2	Sampling Variability, Estimation and Inferences; Bias, Efficiency, Standard Error, Consistency and Robustness in Estimation	3
3	Flood Frequency and Low Flows Analysis based on Annual Minimum, Annual Maximum and Partial Duration Series Models	4
4	Theory of Extremes and Extreme Value Distributions	3
5	Method of Maximum Likelihood, Probability Weighted Moments and L-Moments, Order Statistics, Probability Plotting	4
6	Stochastic Processes; Multiplicative ARIMA models and its various special forms and applications in Time Series Modelling; Markov Chains and Probability Theory of Reservoir Storage,	6
7	Regional FF Analysis	3
8	Least Squares Estimation and applications to Regression Analysis	3
9	Error Propagation	1
10		
11		
12		
COURSE TOTAL (14 times 'L')		28

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Introduction to SPSS, ITSM and FFA software	4
2	Descriptive statistics	2
3	Moments and ML Estimation	4
4	Flood Frequency Analysis of AM and PD Series models	4
5	PWM and L-Moments based Estimation	2
6	Multiplicative ARIMA modelling of Hydrologic Time Series	6
7	Regional FF Analysis	4
8	Least Squares Estimation	2
9		
10		
COURSE TOTAL (14 times 'P')		28

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

1. Kottegoda, N. T., Stochastic water resources technology, London: Macmillan, 1980.
2. Hipel, K. W., and McLeod, A. I., Time series modelling of water resources and environmental systems, Elsevier, 1994.
3. Hamed, K., and Rao, A. R. (Eds.), Flood frequency analysis, CRC press, 2010.
4. Brockwell, P. J., and Davis, R. A., Introduction to time series and forecasting, 2002.
5. Hosking, J. R. M., and Wallis, J. R., Regional Frequency Analysis, Cambridge, UK:

- Cambridge University Press, 1997.
6. Box, G. E., and Jenkins, G. M., Time series analysis: forecasting and control, revised ed. Holden-Day, 1976.
 7. Haan, C. T., Statistical methods in hydrology, 2002.
 8. Johnston, J., and DiNardo, J., Econometric methods, McGraw-Hill: New York, 1997.
 9. Salas, J. D., Applied modeling of hydrologic time series, Water Resources Publication, 1980.
 10. Maass, A., Design of water-resource systems, 1962.
 11. Makridakis, S., Wheelwright, S. C., and Hyndman, R. J., Forecasting methods and applications, John Wiley & Sons, 2008.
 12. Yevjevich, V., Probability and statistics in hydrology, Fort Collins, CO: Water resources publications, 1972.
 13. Kite, G. W., Frequency and risk analysis in water resources, Water Resources, 1988.

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	yes
19.2	Hardware	yes
19.3	Teaching aides (videos, etc.)	Yes
19.4	Laboratory	YES
19.5	Equipment	YES
19.6	Classroom infrastructure	Yes
19.7	Site visits	No

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	20-40
20.2	Open-ended problems	10-20
20.3	Project-type activity	10-20
20.4	Open-ended laboratory work	30-40
20.5	Others (please specify)	10-20; (TERM PAPERS; REVIEW OF PAPERS etc.)

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	ADVANCED HYDRAULICS
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL734
6.	Status (<i>category for program</i>)	PROGRAMME CORE

7.	Pre-requisites (course no./title)	Nil
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	NIL
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	NIL

9.	Not allowed for (indicate program names)	
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☒ 2 nd sem ☐ Either sem
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11.	Faculty who will teach the course All Water Resources faculty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): 1. To study fluid-flow problems, technology associated with such flows and its applications. 2. This course deals with advanced topics in flow of water through open channels, sediment transport and industrial hydraulics.	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Energy and momentum principles in open channel, Curvilinear Flows, Backwater computations, Controls, Rapidly varied flows, Spatially varied flows, Unsteady flow, Surges, Flood wave passage, Roll waves, Sediment transport, Incipient motion criteria, Resistance to flow and bed forms, Bed load theory, Stratified flows, Fluvial Systems, Industrial Hydraulics.	
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15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Energy and momentum principles in open channel,	4
2	Curvilinear Flows	4
3	Backwater computations, Controls	5
4	Rapidly varied flows, Spatially varied flows,	6
5	Unsteady flow, Surges, Flood wave passage, Roll waves,	4
6	Sediment transport, Incipient motion criteria,	4
7	Resistance to flow and bed forms,	3
8	Bed load theory,	4
9	Stratified flows,	2
10	Fluvial Systems,	2
11	Industrial Hydraulics.	4
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		NIL
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		NIL

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

- | | |
|-----|---|
| (1) | Yang, C.T., Sediment Transport: Theory and Practice, McGraw Hill, 1996 |
| (2) | Graf, W.H., Hydraulics of sediment transport, McGraw Hill, 1971 |
| (3) | Raudkivi, A.J., Loose Boundary Hydraulics, Pergamon Press, 2012 |
| (4) | Raju, R. and Garde, J., Mechanics of sediment transport and Alluvial Stream Problems, 3 rd Ed., New Age International, 2000. |

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	
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19.2	Hardware	yes
19.3	Teaching aides (videos, etc.)	yes
19.4	Laboratory	NA
19.5	Equipment	NA
19.6	Classroom infrastructure	yes
19.7	Site visits	

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	60
20.2	Open-ended problems	5
20.3	Project-type activity	15
20.4	Open-ended laboratory work	0
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	FINITE ELEMENTS IN WATER RESOURCES
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL735
6.	Status (<i>category for program</i>)	PROGRAMME CORE

7.	Pre-requisites (course no./title)	Nil
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	Nil
8.2	Overlap with any UG/PG course of other Dept./Centre	Nil
8.3	Supercedes any existing course	CEL742

9.	Not allowed for (indicate program names)	Others than WR
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course Prof. N. K. Garg and other WRE faculty	
12.	Will the course require any visiting faculty?	Nil

13.	Course objective (<i>about 50 words</i>): The students should be able to understand basics of finite elements as applicable in the water resources area and fluids.	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Introduction to finite element method, Mathematical concepts and weighted residual techniques, Spatial discretization, Shape functions, Isoparametric elements, Explicit and implicit time marching schemes, Equation assembly and solution techniques, Application: Navier-Stokes equations, dispersion of pollutants into ground and surface water, Flow through earthen dams, seepage beneath a hydraulic structure, Groundwater flow in confined and unconfined aquifers.	
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15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Introduction to finite element method	2
2	Mathematical concepts and weighted residual techniques (Fluids)	12
3	Spatial discretization, Shape functions	6
4	Isoparametric elements and numerical integration	8
5	Explicit and implicit time marching schemes	2
6	Equation assembly and solution techniques,	3
7	Navier-Stokes equations,	3
8	Dispersion of pollutants into ground and surface water	2
9	Flow through earthen dams, seepage beneath a hydraulic structure,	2
10	Groundwater flow in confined and unconfined aquifers.	2
11		
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

1. Pinder, G. F., Gray, W. G., *Finite Elements in Subsurface Hydrology*, Academic Press, 1977.
 2. Huyakorn, P.S and Pinder, C. F., *Computational Methods in Sub-surface Flow*, Academic Press, 1983.
 3. Connor, J.C. and Brebbia, C. A., *Finite Element Techniques for Fluid Flow*, Butterworth, 1976.
 4. Taylor, C. and Hughes, T. J. *Finite Element programming of the Navier Stokes Equation*, Pineridge Press, 1980.
 5. Finlayson, B. A., *The method of Weighted Residuals and Variational Principles*, Academic Press, 1972.
- Besides these, the international conferences and journals in the area of water

resources and fluid mechanics be referred.

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	Nil
19.2	Hardware	Nil
19.3	Teaching aides (videos, etc.)	Nil
19.4	Laboratory	Nil
19.5	Equipment	Nil
19.6	Classroom infrastructure	Normal
19.7	Site visits	Nil

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	Nil
20.2	Open-ended problems	Nil
20.3	Project-type activity	Nil
20.4	Open-ended laboratory work	Nil
20.5	Others (please specify)	100% (Problems related to Water Resources and Fluids)

Date: 16-02-2015

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	Civil Engineering
2.	Course Title (<i>< 45 characters</i>)	SOFT COMPUTING TECHNIQUES IN WATER RESOURCES
3.	L-T-P structure	2 - 0 - 2
4.	Credits	3
5.	Course number	CVL736
6.	Status (<i>category for program</i>)	PROGRAMME ELECTIVE

7.	Pre-requisites (course no./title)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	IL
8.2	Overlap with any UG/PG course of other Dept./Centre	<20% in Mathematics, CSC courses
8.3	Supercedes any existing course	NIL

9.	Not allowed for (<i>indicate program names</i>)	Programme outside Civil Engineering Department
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☒ 2 nd sem ☐ Either sem
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11.	Faculty who will teach the course Dr Dhanya C.T. and other WRE faculty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): 1. The purpose of this course is to obtain knowledge on various soft computing techniques widely used in water resources engineering.. 2. To forecast the complex systems in water resources engineering using soft computing techniques.	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Artificial Intelligence; Expert Systems; Artificial Neural Networks: Introduction, Training, Applications in Hydrology; Genetic Algorithms; Fuzzy Logic Systems, Fuzzy Set Theory, Predictive and Descriptive Data Mining; Classification Methods: Decision trees, NN, Bayesian, ANN, SVM, Applications; Association Analysis; Cluster Analysis - K-means, Fuzzy, Self-Organising maps; Anomaly detection; Applications in Water Resources - Forecasting, Regionalization	
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15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Introduction to Artificial Intelligence	1
2	Expert System	2
3	Artificial Neural Networks and Applications in Hydrology	5
4	Genetic Algorithms	2
5	Fuzzy Logic Systems	2
6	Fuzzy Set theory	2
7	Data Mining - Applications in Hydrology and Hydroclimatology	1
8	Classification Techniques	5
9	Association rules - Causal relationships	2
10	Cluster Analysis - Regionilization and Other applications	4
11	Anomaly Detection - Extreme events	2
12		
COURSE TOTAL (14 times 'L')		28

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Introduction to Matlab and Libraries	4
2	Application of Soft computing Techniques: (a) Artificial Neural Networks and Applications in Water Resources	6
3	(b) Classification Techniques and Applications in Water Resources	6
4	(c) Association Analysis and Applications in Water Resources	6
5	(d) Cluster Analysis and Applications in Water Resources	4
6	(e) Anomaly Detection and Applications in Water Resources	2
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		28

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

- (1) Winston, P.H. Artificial Intelligence, Pearson Education, 1999.
- (2) Goldberg, D.E. Genetic Algorithms, Addison Wesley Longman, 1999.
- (3) Haykin, S. Neural Networks: A comprehensive Foundation, Second Edition, Prentice Hall, New Jersey, USA, 1999.
- (4) Zimmermann, H.-J. Fuzzy Set Theory and its Applications, Kluwer Academic, Boston, 1985.
- (5) Han, J., Kamber, M., and Pei, J., Data Mining: Concepts and Techniques, Morgan Kaufmann, 2011

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	Matlab, Data Mining Softwares
19.2	Hardware	yes
19.3	Teaching aides (videos, etc.)	yes
19.4	Laboratory	Existing
19.5	Equipment	Existing
19.6	Classroom infrastructure	yes
19.7	Site visits	

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	0
20.2	Open-ended problems	10
20.3	Project-type activity	15
20.4	Open-ended laboratory work	10
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	ENVIRONMENTAL DYNAMICS AND MANAGEMENT
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL737
6.	Status (<i>category for program</i>)	PROGRAMME ELECTIVE

7.	Pre-requisites (course no./title)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	NIL
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	CEL736

9.	Not allowed for (indicate program names)	Nil
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course Dr. S. Chakma, Prof. S. Mathur and other WRE faculty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): 1. Understanding, modelling of environmental processes and systems. 2. Study of Environmental dynamics and its application.	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Environmental property and processes, Environmental simulation models, Elements of environmental impact analysis, Impact assessment methodologies, Framework of environmental assessment, Environmental impact of water resources projects, Assessment of hydrological hazards, Environmental management, Case studies.	
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15. Lecture Outline (*with topics and number of lectures*)

Module no.	Topic	No. of hours
1	Introduction	1
2	Environmental property and processes	2
3	Environmental simulation models	2
4	Population dynamics and different models	3
5	Discrete logistic growth, oscillations, and chaos	4
6	Competition between two species, mutualism, and species invasions	3
7	Time series analysis and its applications in environmental modelling	6
8	Introduction to Environmental Impact Assessment	3
9	Traditional Approaches for Environmental Impact Assessment	6
10	Fuzzy Logic - Introduction	4
11	Fuzzy Logic based Environmental Impact Assessment	4
12	Environmental Impact of Water Resources Projects	4
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		Nil
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		Nil

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

- (1) Pastor, J., *Mathematical Ecology of Populations and Ecosystems*, Wiley & Sons Ltd, 2008
- (2) Wainwright, J., and Mulligan, *Environmental Modelling*, John Wiley & Sons Ltd, 2013.
- (3) Sen, Z., *Fuzzy Logic and Hydrological Modeling*, CRC Press, 2009.
- (4) Gore, A., and Paranjpe, K., *A Course in Mathematical and Statistical Ecology*, Springer 2001
- (5) Jayawardenen, A. W., *Environmental and Hydrological Systems Modelling*, CRC Press, 2013.
- (6) Nimalakhandan, *Modeling Tools for Environmental Engineers and Scientists*, CRC Press, 2002.
- (7) Pielou, E.C., *An introduction to mathematical ecology*, Wiley-Interscience, 1969

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19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	No
19.2	Hardware	yes
19.3	Teaching aides (videos, etc.)	yes
19.4	Laboratory	Existing
19.5	Equipment	Existing
19.6	Classroom infrastructure	yes
19.7	Site visits	

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	30-40
20.2	Open-ended problems	30-40
20.3	Project-type activity	20-40
20.4	Open-ended laboratory work	-
20.5	Others (please specify)	20-40; (TERM PAPERS, REVIEW OF ARTICLES etc.)

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	Civil Engineering
2.	Course Title (<i>< 45 characters</i>)	ECONOMIC ASPECTS OF WATER RESOURCES DEVELOPMENT
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL738
6.	Status (<i>category for program</i>)	PROGRAMME ELECTIVE

7.	Pre-requisites (course no./title)	Nil
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	NIL
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	CEL743

9.	Not allowed for (indicate program names)	Nil
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course Dr. Sumedha Chakma, Shashi Mathur & other WRE Faculty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): 1. To impart basic economic concepts to water resources. 2. To study integrated hydro-economic modeling, water resources valuation, risk assessment and evaluation of water pricing.	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Economics of water and development, Basic economic concepts, Financial analysis of a project, Pricing concepts, Benefit-cost-sensitivity analysis, Capital budgeting and cost allocation, Economics of natural resources management, Hydro economic model, Hydro-economic risk assessment, Economics of river restoration, Economics of trans-boundary water resources management.	
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15. Lecture Outline (*with topics and number of lectures*)

Module no.	Topic	No. of hours
1	Economics of water and development	4
2	Basic economic concepts,	4
3	Finanacial analysis of a project,	4
4	Pricing concepts,	4
5	Benefit-cost-sensitivity analysis,	4
6	Capital budgeting and cost allocation,	4
7	Economics of natural resources management,	4
8	Hydro economic model,	4
9	Hydro-economic risk assessment,	4
10	Economics of river restoration,	3
11	Economics of trans-boundary water resources management.	3
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	NA	NA
2	NA	NA
3	NA	NA
4	NA	NA
5	NA	NA
6	NA	NA
7	NA	NA
8	NA	NA
9	NA	NA
10	NA	NA
COURSE TOTAL (14 times 'P')		NA

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

- (1) Vashishtha, P., Water Resources, Management & Economic Development, Pointer Publishers, 1st Ed., 2010.
- (2) Panneerselvam, R., Engineering Economics, 2nd Ed., PHI, 2014.
- (3) Haimes, Y. Y., et al., Risk-Based Decision making in Water Resources IX, ASCE, 2001.
- (4) Griffin, R.C., Water Resource Economics, 1st Ed., MIT Press, 2005.
- (5) U.S.D.A., Water Resources Handbook for Economics, 1st Ed. NREH, 1998.

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	No
19.2	Hardware	No
19.3	Teaching aides (videos, etc.)	No
19.4	Laboratory	No
19.5	Equipment	No
19.6	Classroom infrastructure	No
19.7	Site visits	No

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	0
20.2	Open-ended problems	Uto 10
20.3	Project-type activity	Uto 20
20.4	Open-ended laboratory work	0
20.5	Others (please specify)	Upto 70 (Self study)

Date: 10-03-2015

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	Civil Engineering
2.	Course Title (<i>< 45 characters</i>)	GROUNDWATER FLOW AND POLLUTION MODELLING
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL830
6.	Status (<i>category for program</i>)	PROGRAMME ELECTIVE

7.	Pre-requisites (course no./title)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	NIL
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	CEL744

9.	Not allowed for (indicate program names)	NIL
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☒ 2 nd sem ☐ Either sem
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11.	Faculty who will teach the course Prof. A. K. Keshari, Prof. B.R. Chahar and other WRE faculty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): 1. To understand lithology, subsurface processes, porous media characteristics, flow through porous media, unsaturated flows and multiphase flows 2. To understand contaminant transport mechanisms, including physical, chemical and biological processes, through porous media and in subsurface and groundwater/aquifer systems 3. To learn mathematical and numerical models for addressing groundwater flow and contaminant transport problems and to evolve management strategies for optimum utilization of groundwater resources, pollution control and aquifer restoration/remediation	
14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Subsurface processes and concepts for groundwater resources evaluation, Unsaturated zone properties: Soil moisture levels, Retention curves, Flow through unsaturated porous media, Multiphase flows, infiltration and Wetting	

	front, Groundwater contamination, Sources and causes of groundwater pollution, Pollution dynamics, Hydrodynamics dispersion, Adsorption, Biodegradation, Radioactive decay, Reactive processes, Multiphase contamination, NAPLs, VOCs, Site specific groundwater quality problems in Indian context, Numerical models, Finite difference methods, Numerical modeling of steady and transient flows in saturated and unsaturated domain, Contaminant transport modeling, Application of FEM and BIEM in groundwater modeling, Regional aquifer simulation, Contaminated groundwater systems and their rehabilitation, Development and optimization based management of aquifer systems, Stochastic models, Random field concepts in groundwater models; Application of emerging techniques to groundwater management.
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15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours
1	Introduction	1
2	Subsurface processes and concepts for groundwater resources evaluation, Infiltration and Wetting front	4
3	Unsaturated zone properties and Flow through unsaturated porous media, Multiphase flows	6
4	Groundwater contamination, Sources and causes of groundwater pollution	3
5	Pollution dynamics, Contaminant transport mechanisms, Hydrodynamics dispersion, Advection-Dispersion Equation, Analytical models for contaminant transport	6
6	Adsorption, Biodegradation, Radioactive decay, Reactive processes, Multiphase contamination, NAPLs	4
7	Mathematical models and FDMs, Numerical modelling of steady and transient flows in saturated and unsaturated porous media, Contaminant transport modelling	7
8	Application of FEM and BIEM in groundwater modeling	2
9	Regional aquifer simulation, Contaminated groundwater systems and their rehabilitation	3
10	Development and optimization based management of aquifer systems	3
11	Stochastic models and Random field concepts in groundwater models	2
12	Application of emerging techniques to groundwater management	1
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		Nil

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

- (1) Bear, J. and Verruijt, A., *Modelling Groundwater Flow and Pollution*, D. Reidel Publishing Company, 1987.
 (2) Bear, J., *Hydraulics of Groundwater*, McGraw-Hill, 1979.

- (3) Remson, I., Hornberger, G.M. and Molz, F.J., Numerical Methods in Subsurface Hydrology, Wiley-Interscience
- (4) Huyakorn, P.S. and Pinder, G.F., Numerical Methods in Subsurface Flow, Academic Press, 1983
- (5) Chow, V.T., Maidment, D.R., and Mays, L.W., Applied Hydrology. McGraw-Hill, Series in Water Resources and Environmental Engineering, 1988.
- (6) Keshari, A.K., Recent Trends in Groundwater Sector in India. Japan International Cooperation Agency (JICA), 2003.
- (7) Bhattacharya, P., Ramanathan, AL., Mukherjee, A., Bundschuh, J., Chandrashekharam, D. and Keshari, A.K., Groundwater for Sustainable Development: Problems, Perspectives and Challenges. CRC Press/Balkema-Taylor & Francis, 2008.
- (8) Ramanathan, AL., Bhattacharya, P., Keshari, A.K., Bundschuh, J., Chandrashekharam, D. and Singh, S.K., Assessment of Groundwater Resources and Management. I.K. International Publishing House, New Delhi, 2008.

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	Yes (preferable)
19.2	Hardware	Yes
19.3	Teaching aides (videos, etc.)	Yes
19.4	Laboratory	No
19.5	Equipment	No
19.6	Classroom infrastructure	Yes
19.7	Site visits	Yes (preferable)

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	40
20.2	Open-ended problems	25
20.3	Project-type activity	35
20.4	Open-ended laboratory work	0
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)

INDEPENDENT STUDY TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	INDEPENDENT STUDY
3.	L-T-P structure	0 - 3 - 0
4.	Credits	3
5.	Course number	CVS830
6.	Status (<i>category for program</i>)	PROGRAMME ELECTIVE

7.	Pre-requisites (course no./title)	NONE
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8.	Supersedes any existing course	NONE
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9.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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10.	FACULTY WHO WILL SUPERVISE PROJECT STUDY ALL WATER RESOURCES FACULTY	
11.	Will the PROJECT SUPERVISION require any visiting faculty?	MAY BE INVITED ON REQUEST BY FACULTY SUPERVISOR/STUDENT

12.	PROJECT objective (<i>about 50 words</i>): TO STUDY AN IDENTIFIED RESEARCH AREA AND PREPARE A REPORT ON THE STATE OF THE ART	
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13. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	SPECIFIC TO THE PROBLEM TAKEN UP FOR THE STUDY	OPEN

14. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

RELEVANT, CONTEXTUAL RESEARCH ARTICLES, REPORTS AND BOOKS

15. Resources required for the STUDY (*itemized & student access requirements, if any*)

19.1	Software	YES
19.2	Hardware	YES
19.3	PRESENTATION aides (videos, etc.)	YES
19.4	Laboratory	YES
19.5	Equipment	YES
19.6	Classroom infrastructure	NO
19.7	Site visits	MAY BE REQUIRED AS PART OF THE STUDY

Date:

(Signature of the Head of the Department)

MAJOR PROJECT TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	MAJOR PROJECT I
3.	L-T-P structure	0 - 0 - 12
4.	Credits	6
5.	Course number	CVD831
6.	Status (<i>category for program</i>)	PROGRAMME CORE
7.	Pre-requisites (<i>course no./title</i>)	EARNED ROGRAMME CORE CREDITS AND MINIMUM OF 24 CREDITS BY THE END OF FIRST YEAR
8.	Supersedes any existing course	CED 841
9.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
10.	FACULY WHO WILL SUPERVISE PROJECT STUDY ALL WATER RESOURCES FACULTY	
11.	Will the PROJECT SUPERVISION require any visiting faculty?	MAY BE INVITED ON REQUEST BY FACULTY SUPERVISOR/STUDENT
12.	PROJECT objective (<i>about 50 words</i>): (1) TO INITIATE STUDENTS INTO RESEARCH ON WELL DEFINED OR OPEN ENDED PROBLEMS (2) TO FOSTER/PROMOTE UNDERSTANDING OF IDENTIFIED HYDRO-ECO-CLIMATOLOGICAL RESOURCES RELATED PROBLEM DOMAINS BASED ON GLOBAL/REGIONAL/LABORATORY SCALE BASED EXPERIMENTS AND/OR NUMERICAL MODELLING BASED APPROACHES (3) TO DEVELOP THEORETICAL FORMULATIONS OF SPECIFIC CONTEXTUAL PHYSICAL PROCESSES (4) TO DEVELOP IMPROVED DESIGN METHODOLOGIES IN THE AREA OF WATER RESOURCES ENGINEERING (5) TO DEVELOP RIVER BASIN SCALE LONG TERM INTEGRATED PLANNING AND MANAGEMENT PERSPECTIVES FOR HYDRO-ECO-CLIMATOLOGICAL RESOURCES WITHIN A MULTI-SITE, MULTI-USER, MULTI-PURPOSE AND MULTI-OBJECTIVE FRAMEWORK	

13. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	SPECIFIC TO THE PROBLEM TAKEN UP FOR THE STUDY	OPEN

14. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

RELEVANT, CONTEXTUAL RESEARCH ARTICLES, REPORTS AND BOOKS

15. Resources required for the STUDY *(itemized & student access requirements, if any)*

19.1	Software	YES
19.2	Hardware	YES
19.3	PRESENTATION aides (videos, etc.)	YES
19.4	Laboratory	YES
19.5	Equipment	YES
19.6	Classroom infrastructure	NO
19.7	Site visits	MAY BE REQUIRED AS PART OF THE STUDY

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	Civil Engineering
2.	Course Title (<i>< 45 characters</i>)	SURFACE WATER QUALITY MODELING AND CONTROL
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL831
6.	Status (<i>category for program</i>)	PROGRAMME ELECTIVE

7.	Pre-requisites (course no./title)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	NIL
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	CEL 741

9.	Not allowed for (indicate program names)	
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course All Water Resources faculty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): 1. To provide better understanding of the various interactions and mechanics of surface water pollution. 2. Fundamentals and principles of various modeling techniques relied on to analyze the quality of surface water in rivers, lakes and estuaries. 3. To provides the various environmental control techniques and strategies so as to obtain water use objectives through a control program.	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): River hydrology and derivation of Stream Equation, Derivation of Estuary equation, Distribution of water quality in rivers and estuaries. Physical and Chemical characteristics of Lakes, Finite Difference steady state river, estuary and Lake models., Dissolved Oxygen models in rivers, estuaries and Lakes, Fate of Indicator Bacteria and pathogens in water bodies. Basic Mechanism of Eutrophication, Lake phytoplankton models, eutrophication in rivers and	
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	estuaries. Elements of Toxic substance analysis
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15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	River hydrology and derivation of Stream Equation	2
2	Derivation of Estuary equation, water quality in rivers and estuaries	6
3	Characteristics of lake and water quality models in lakes	6
4	Dissolved Oxygen models in rivers, estuaries and Lakes	6
5	Bacteria, virus and pathogens in water bodies	2
6	Mechanisms of Eutrophication	3
7	Lake phytoplankton models	6
8	Eutrophication and rivers and estuaries	4
9	Toxic substance analysis	4
10	Temperature, Heat balance models in water bodies	3
11		
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		Nil

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

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|---|
| (1) Thomann R. V. and J A Mueller, Principles of Surface Water Quality Modeling and Control, Harper and Row, 1987
(2) Chapra, Steven, C., Surface Water Quality Modeling, Mc Graw Hill, 1997
(3) Hammer, Mark, J., Water and Wastewater Technology, John Wiley, 1977
(4) Peavy, H. S., Donald, R. R. and George Tchobanoglous, Environmental Engineering, Mc Graw Hill, 1986 |
|---|

19. Resources required for the course *(itemized & student access requirements, if any)*

19.1	Software	yes
19.2	Hardware	yes
19.3	Teaching aides (videos, etc.)	yes
19.4	Laboratory	no
19.5	Equipment	no
19.6	Classroom infrastructure	yes
19.7	Site visits	no

20. Design content of the course *(Percent of student time with examples, if possible)*

20.1	Design-type problems	60
20.2	Open-ended problems	5
20.3	Project-type activity	15
20.4	Open-ended laboratory work	10
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)

MAJOR PROJECT TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	MAJOR PROJECT II
3.	L-T-P structure	0 - 0 - 24
4.	Credits	12
5.	Course number	CVD832
6.	Status (<i>category for program</i>)	PROGRAMME CORE

7.	Pre-requisites (course no./title)	STUDENT SHOULD HAVE CLEARED MAJOR PROJECT PART I – CVD831
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8.	Supersedes any existing course	CED 842
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9.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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10.	FACULY WHO WILL SUPERVISE PROJECT STUDY ALL WATER RESOURCES FACULTY	
11.	Will the PROJECT SUPERVISION require any visiting faculty?	MAY BE INVITED ON REQUEST BY FACULTY SUPERVISOR/STUDENT

12.	PROJECT objective (<i>about 50 words</i>): (1) TO INITIATE STUDENTS INTO RESEARCH ON WELL DEFINED OR OPEN ENDED PROBLEMS (2) TO FOSTER/PROMOTE UNDERSTANDING OF IDENTIFIED HYDRO-ECO-CLIMATOLOGICAL RESOURCES RELATED PROBLEM DOMAINS BASED ON GLOBAL/REGIONAL/LABORATORY SCALE BASED EXPERIMENTS AND/OR NUMERICAL MODELLING BASED APPROACHES (3) TO DEVELOP THEORETICAL FORMULATIONS OF SPECIFIC CONTEXTUAL PHYSICAL PROCESSES (4) TO DEVELOP IMPROVED DESIGN METHODOLOGIES IN THE AREA OF WATER RESOURCES ENGINEERING (5) TO DEVELOP RIVER BASIN SCALE LONG TERM INTEGRATED PLANNING AND MANAGEMENT PERSPECTIVES FOR HYDRO-ECO-CLIMATOLOGICAL RESOURCES WITHIN A MULTI-SITE, MULTI-USER, MULTI-PURPOSE AND MULTI-OBJECTIVE FRAMEWORK	
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13. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	SPECIFIC TO THE PROBLEM TAKEN UP FOR THE STUDY	OPEN

14. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

RELEVANT, CONTEXTUAL RESEARCH ARTICLES, REPORTS AND BOOKS

15. Resources required for the STUDY *(itemized & student access requirements, if any)*

19.1	Software	YES
19.2	Hardware	YES
19.3	PRESENTATION aides (videos, etc.)	YES
19.4	Laboratory	YES
19.5	Equipment	YES
19.6	Classroom infrastructure	NO
19.7	Site visits	MAY BE REQUIRED AS PART OF THE STUDY

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	HYDROELECTRIC ENGINEERING
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL832
6.	Status (<i>category for program</i>)	PROGRAMME ELECTIVE

7.	Pre-requisites (course no./title)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	<15% (WATER POWER ENGINEERING)
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	CEL746

9.	Not allowed for (indicate program names)	
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☒ 2 nd sem ☐ Either sem
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11.	Faculty who will teach the course R. KHOSA, A.K. KESHARI, D.R. KAUSHAL AND OTHER WATER RESOURCES FACULTY	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): 1. To develop an understanding of issues pertaining to planning, analysis and design of various components of hydropower projects within an integrated Energy Planning and Management System 2. Implications of hydro projects on water resources, environment, socio-economics and national economy. 3. To develop an understanding of the dynamic response of a hydropower generating facility to governor interventions and the resulting propagation of hydraulic transients 4. To develop an understanding of the phenomenon of mass oscillations within an integrated reservoir-surge tank-hydropower plant system	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>):	
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	Hydropower development schemes and their various configurations, Planning for firm Capacities, Peak Load and Base Load configurations, Role of and Regulation of Hydropower development in a mixed hydro-steam system, Governing of Hydropower systems; study of hydraulic transients in Penstocks. Surge analysis and dynamics of Surge tanks. Micro hydro power developments.
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15. Lecture Outline (*with topics and number of lectures*)

Module no.	Topic	No. of hours
1	Hydropower systems: planning and configurations	2
2	Functional classification, Operations within a mixed hydro-steam system	3
3	Load analysis and design of firm capacity	4
4	Regulatory framework within a growing mixed hydro-steam system	4
5	Introduction to hydraulic transients and methods of analysis	5
6	Elastic theory for transient analysis	8
7	Reflection and transmission characteristics of pressure waves	3
8	Allievi's approach and solution by Method of Characteristics	3
9	Analysis of Surges and Surge Tank configurations	8
10	Micro-hydro plants	2
11		
12		
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
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10		
COURSE TOTAL (14 times 'P')		Nil

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

1. Creager, W. P., and Justin, J. D. W., *Hydroelectric handbook*, 1950.
2. Watters, G. Z., *Analysis and control of unsteady flow in pipelines*, Boston: Butterworths, 1984.
3. Fox, J. A., *Hydraulic analysis of unsteady flow in pipe networks*, Halsted Press, 1977.
4. Pickford, J., *Analysis of surge*, London, UK: Macmillan, 1969.
5. Kuiper, E., *Water Resources Development; planning, engineering and economics*, 1965.
6. Wylie, E. B., Streeter, V. L., and Suo, L., *Fluid transients in systems*, Englewood Cliffs, NJ: Prentice Hall, 1993.
7. Streeter, V. L., and Wylie, E. B., *Hydraulic transients*, 1967.
8. Mosonyi, E., *Water Power Development: Low-Head Hydropower Utilization*,

Developments in Hydraulic Engineering-, 5, 1988.

9. Inversin, A. R., Micro-hydropower source book. National rural electric cooperative association (NRECA), International Foundation, Washington, 1986.

10. Uli-Meir, Local Experience with Micro-hydro Technology , SKAT – ATOL, St. Gallen, 1985.

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	yes
19.2	Hardware	yes
19.3	Teaching aides (videos, etc.)	yes
19.4	Laboratory	no
19.5	Equipment	no
19.6	Classroom infrastructure	yes
19.7	Site visits	yes(preferable if institute allocates money)

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	30-40
20.2	Open-ended problems	30-40
20.3	Project-type activity	30-40
20.4	Open-ended laboratory work	NIL
20.5	Others (please specify)	NIL

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	WATER RESOURCES SYSTEMS
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL833
6.	Status (<i>category for program</i>)	PROGRAMME ELECTIVE

7.	Pre-requisites (course no./title)	CVL730; CVL731; CVL733
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	NIL
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	CEL749

9.	Not allowed for (indicate program names)	
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☒ 2 nd sem ☐ Either sem
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11.	Faculty who will teach the course R. KHOSA, A.K. GOSAIN, C.T. DHANYA, R. MAHESWARAN	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): (1) To develop understanding of Integrated Water Resources Planning, Development and Management concepts on River Basin Scale (2) To develop concepts for efficient management of Water Resources within a multi-user, multi-component, multi-purpose and a multi-objective framework (3) To identify sources of uncertainty in Water Resources Systems Planning (4) To develop modelling paradigms that accommodate role of uncertainty in Basin Scale Water Resources Planning	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Water Resources Planning Purposes and Objectives, Multi-component, multi-user, multi-objective and multi-purpose attributes of an Integrated Water Resources System, Economic basis for selection of a Plan Alternative Introduction to Linear Programming and applications in Water Resources Engg	
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	Irrigation Planning and Operation Models, Linear, Deterministic Integrated Water Resources Management Model on River Basin Scale, River Basin Scale Integratd Stochastic Water Resources Planning and Management Models.
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15. Lecture Outline (*with topics and number of lectures*)

Module no.	Topic	No. of hours
1	Scope and Nature of a Water Resources System	3
2	Water Resources Development Purposes and Planning Objectives	2
3	Introduction to Principles of Economic Analysis	3
4	Introduction to Multi-Objective Analysis	4
5	Reservoir Sizing and Design	2
6	Environmental and Water Quality aspects of River Basin Management	3
7	Structural Flood Control alternatives and estimation of capacities	4
8	Integrated Deterministic Multi-purpose, Multi-component River Basin Planning Model	5
9	Dynamic and Integer Programming based capacity expansion planning	3
10	Simulation based Multi-Goal modelling for Water Management	4
11	Irrigation Planning and Operation Modelling	5
12	Yield models and uncertainty in Water Resources Management Planning	4
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
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9		
10		
COURSE TOTAL (14 times 'P')		Nil

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

- 1) Loucks, D.P., Stedinger, J.R., and Haith, D.A., *Water Resources Systems Planning and Analysis*, 1st Ed., Prentice Hall, 1981.
- 2) ReVelle, C.S., Whitlatch Jr, E.E., and Wright, J.R., *Civil and Environmental Systems Engineering*, Pearson Prentice Hall, 2004.
- 3) Smith, A. A., Hinton, E., and Lewis, R.W., *Civil Engineering Systems Analysis and Design*, John Wiley and Sons, 1983.
- 4) James, L.D., and Lee, R.R., *Economics of Water Resources Planning*, McGraw-Hill, 1971.
- 5) Vedula, S., and Mujumdar, P.P., *Water Resources Systems: Modelling Techniques and*

Analysis, Tata McGraw-Hill, 2005.

- 6) Loucks, D. P., Van Beek, E., Stedinger, J. R., Dijkman, J. P., and Villars, M. T., Water resources systems planning and management: an introduction to methods, models and applications, Paris: UNESCO, 2005.
- 7) Kuiper, E., Water Resources Development; planning, engineering and economics, 1965.
- 8) Deb, K., Multi-objective optimization using evolutionary algorithms, Vol. 16, John Wiley & Sons, 2001.
- 9) Wurbs, R. A., and James, W. P., Water resources engineering. Prentice Hall, 2002.
- 10) Mays, L., Optimal control of hydrosystems, CRC Press, 1997.
- 11) Loucks, D. P., and da Costa, J. R., Decision support systems: Water resources planning, Springer Publishing Company, Incorporated, 2013.
- 12) Esogbue, A. O., Dynamic Programming for Optimal Water Resource Systems Analysis, Prentice Hall PTR, 1989.

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	yes
19.2	Hardware	yes
19.3	Teaching aides (videos, etc.)	Yes
19.4	Laboratory	no
19.5	Equipment	no
19.6	Classroom infrastructure	Yes
19.7	Site visits	No

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	20-40
20.2	Open-ended problems	30-40
20.3	Project-type activity	30-40
20.4	Open-ended laboratory work	NIL
20.5	Others (please specify)	20-30; (TERM PAPER; REVIEW OF ARTICLES etc.)

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	Civil Engineering
2.	Course Title (<i>< 45 characters</i>)	URBAN WATER INFRASTRUCTURE
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL834
6.	Status (<i>category for program</i>)	PROGRAMME ELECTIVE

7.	Pre-requisites (course no./title)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	NIL
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	NIL

9.	Not allowed for (indicate program names)	NIL
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course Prof. A. K. Keshari, Prof. R. Khosa, Prof. A. K. Gosain, Dr. C. T. Dhanya	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): 1. To understand urban water cycle and its role in the designs of urban water infrastructures - water supply, storm water drainage, sanitation, sewerage and wastewater conveyance infrastructures and its rehabilitation and augmentation 2. To understand sustainability concepts and how to carry out sustainable urban designs. 3. To learn about emerging sustainable materials and its hydraulic, structural strength and resilience properties, and design procedures for water supply and sewer pipelines. 4. To learn urban water management practices and its effect on urban water infrastructure, hydrology and groundwater regime.	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Urban water cycle, Urban water infrastructures - water supply, storm water drainage, sanitation, sewerage and wastewater conveyance infrastructures,	
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	Water supply and sewerage network hydraulics, SCADA systems, Sustainable urban designs, Methodologies for assessing sustainability of urban water infrastructures, Emerging sustainable materials and design procedures for water supply and sewerage pipelines, Hydraulic performance and structural strength, chemical resistance and resilience characteristics of emerging materials based water and sewer pipelines, Rehabilitation and augmentation technologies for water supply and sewerage networks, Analytic hierarchy process and optimization techniques for arriving at the best appropriate rehabilitation/ augmentation technology, Urban water management, Rain water harvesting, Managed aquifer recharge, Constructed/engineered wetlands, Sprinkler and drip irrigation, Water use efficiencies, Effect of water management practices on urban water infrastructure, hydrology and groundwater regime, Surface and subsurface mapping of water supply and sewerage networks, Structural safety and mitigating plans against natural and human caused threats.
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15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Urban water cycle, Urban water infrastructures - water supply, storm water drainage, sanitation and wastewater conveyance infrastructures	4
2	Water supply and sewerage network hydraulics, SCADA systems	4
3	Sustainable urban designs, Methodologies for assessing sustainability of urban water infrastructures	3
4	Emerging sustainable materials and design procedures for water supply and sewerage pipelines	4
5	Hydraulic performance and structural strength, chemical resistance and resilience characteristics of emerging materials based water and sewer pipelines	4
6	Rehabilitation and augmentation technologies for water supply and sewerage networks	4
7	Analytic hierarchy process and optimization techniques for arriving at the best appropriate rehabilitation/ augmentation technology	4
8	Urban water management, Rain water harvesting, Managed aquifer recharge	4
9	Constructed/engineered wetlands, Sprinkler and drip irrigation, Water use efficiencies	4
10	Effect of water management practices on urban water infrastructure, hydrology and groundwater regime	2
11	Surface and subsurface mapping of water supply and sewerage networks	3
12	Structural safety and mitigating plans against natural and human caused threats.	2
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		Nil

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

- (1) Grigg, N.S., Water, Wastewater, and Stormwater Infrastructure Management, Second Edition, CRC Press, 2012
- (2) Lazaro, T.R., Urban Hydrology, CRC Press, 1990
- (3) WEF and ASCE, Existing Sewer Evaluation and Rehabilitation, McGraw-Hill, 2009
- (4) Keshari, A.K., Rainwater Harvesting. Water Digest, 1(2): 46-50, 2006.
- (5) Smith, S.W., Landscape Irrigation: Design and Management, 1st Edition, Wiley, 1996
- (6) SAATY, T.L., Decision Making for Leaders, 3rd Revised Edition, RWS Publications, 2012
- (7) Mays, L.W., Hydraulic Design Handbook, McGraw-Hill, 1999

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	No
19.2	Hardware	No
19.3	Teaching aides (videos, etc.)	Yes
19.4	Laboratory	No
19.5	Equipment	Yes
19.6	Classroom infrastructure	Yes
19.7	Site visits	Yes (preferable)

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	50
20.2	Open-ended problems	20
20.3	Project-type activity	30
20.4	Open-ended laboratory work	0
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	CIVIL ENGINEERING
2.	Course Title (<i>< 45 characters</i>)	ECOHYDROLOGY AND HYDRAULICS
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL835
6.	Status (<i>category for program</i>)	PROGRAMME ELECTIVE

7.	Pre-requisites (course no./title)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	NIL
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	NIL

9.	Not allowed for (indicate program names)	Nil
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course B.R. Chahar, S. Chakma, A.K. Gosain and other WRE Faculty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): (1) To develop an understanding of the hydraulic transport phenomena that governs the dynamics of interlinked web of hydro-ecological processes of open surface systems such as rivers, estuaries, inland water bodies, wetlands and coastal systems. (2) To develop a mathematical description of these hydro-ecological systems	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Classification of Hydro environmental systems, governing equations for open surface flow domains, pollutant transport equations in hydro-environmental flow systems, computational methods and solution techniques. Study of ecological descriptors, numerical ecology, multi-objective definitions of environmental flows, Hydrologic indices for e-flows and river health assesment. Riverine habitat characterization and habitat simulation models. Anthropogenic triggers for changes in riverine habitat	
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15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to Hydro-environmental systems	1
2	Classification of Hydro-environmental systems such as Rivers, Lakes and other inland water bodies, wetlands, estuaries and other coastal systems, Underground systems	4
3	Governing equations for open surface flows	5
4	Pollutants and other transport equations of hydro-environmental flow systems	3
5	Computational methods and simulation	6
6	Ecological descriptors and ecological resemblance measures	5
7	Dimensional Analysis in Ecology	4
8	Ecological data and clusters	4
9	Multi-objectives based E-flows definition	2
10	Hydrologic indices for e-flows	2
11	Riverine habitat, river health assessment and habitat simulation models	4
12	Riverine environmental changes under anthropogenic influences	2
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		
2		
3		
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7		
8		
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10		
COURSE TOTAL (14 times 'P')		

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

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|-----|---|
| (1) | Mathematical Ecology of Populations and Ecosystems, by John Pastor, John Wiley & Sons Ltd, 2008 |
| (2) | Environmental Modelling by John Wainwright and Mulligan, John Wiley & Sons, Ltd, 2013. |
| (3) | Fuzzy Logic and Hydrological Modeling, by Zekai Sen, CRC Press, 2009. |
| (4) | A Course in Mathematical and Statistical Ecology, Anil Gore and Paranjpe, by Springer 2001 |
| (5) | Environmental and Hydrological Systems Modelling by A W Jayawardenen, CRC |

Press, 2013.

(6) Modeling Tools for Environmental Engineers and Scientists by Nirmalakhandan, CRC Press, 2002.

(7) An introduction to mathematical ecology, Pielou, E. C, Wiley-Interscience, 1969

(8) Legendre, P., and Legendre, L., Numerical Ecology, Third Edition. Elsevier, 2012

(9) Nassehi, V, and Das, B.D., Computational methods in the Management of Hydro-Environmental Systems. IWA Publishing. 2007

(10) Dodds, W. and Whiles, M., Freshwater Ecology: Concepts & Environmental Applications of Limnology. Second Edition. Academic Press. 2002

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	Yes
19.2	Hardware	yes
19.3	Teaching aides (videos, etc.)	yes
19.4	Laboratory	No
19.5	Equipment	No
19.6	Classroom infrastructure	yes
19.7	Site visits	

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	20-40
20.2	Open-ended problems	20-40
20.3	Project-type activity	20-40
20.4	Open-ended laboratory work	NIL
20.5	Others (please specify)	20-40; (TERM PAPERS etc.)

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	Civil Engineering
2.	Course Title (<i>< 45 characters</i>)	ADVANCED HYDROLOGIC LAND SURFACE PROCESSES
3.	L-T-P structure	3 - 0 - 0
4.	Credits	3
5.	Course number	CVL836
6.	Status (<i>category for program</i>)	PROGRAMME ELECTIVE

7.	Pre-requisites (course no./title)	Nil
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	NIL
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	NIL

9.	Not allowed for (indicate program names)	Nil
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course Dr Dhanya C.T. and other WRE faculty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): 1. To explore the interaction between terrestrial ecosystems and climate change. 2. To impart the knowledge of meteorological, hydrological, ecological concepts for examine the processes by which terrestrial ecosystems affect the climate.	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Introduction: Eco-hydro-climatology; Climate System; Climate, weather and Climate Change; Water, Energy and Carbon Cycle; Overview of Earth's Atmosphere: Heat-Balance of Earth Atmosphere System; Temporal Variation of Air temperature; Introduction to Atmospheric Thermodynamics: First and second law of thermodynamics, Adiabatic process and adiabatic lapse rate, Entropy, Clausius-Clapeyron Theory, Introduction to cloud microphysics and cloud droplet formation process, Cloud liquid water content, entrainment, warm and cold cloud. Hydrologic Cycle: Global water balance; Precipitation and Weather, Forms of Precipitation; Atmospheric Stability; Monsoon; Global Wind	
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	Circulation; Indian Summer Monsoon Rainfall. Climate Variability: Floods, Droughts, Climate Extremes. Climate Change: Introduction; Causes and Modeling of Climate Change, Climate Models, Downscaling; IPCC Scenarios; Commonly used Statistical Methods in Hydro-climatology: Trend Analysis; EOF, PCA; Canonical Correlation; Statistical Downscaling; Ecological Climatology: Leaf energy fluxes and leaf photosynthesis; Ecosystem and vegetation dynamics; Coupled climate vegetation dynamics, Carbon cycle climate feedbacks
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15. Lecture Outline (*with topics and number of lectures*)

Module no.	Topic	No. of hours
1	Introduction; Climate System; Energy and Carbon cycle	2
2	Overview of Earth's Atmosphere; Vertical Structure; Radiation	3
3	Heat balance; Temperature variation; Thermal time and temperature extremes	4
4	Introduction to Atmospheric Thermodynamics; Laws; Processes; Entropy	5
5	Introduction to cloud microphysics; Process of droplet formation; Entrainment; Warm and Cold Cloud	3
6	Hydrologic Cycle; Global water balance; Cycling of water; Water Balance	2
7	Precipitation and weather; Humidity; Vapor Pressure; Forms and Types of Precipitation	3
8	Clouds; Atmospheric Stability; Monsoon; Wind Patterns; Indian Summer Monsoon Rainfall	3
9	Climate Variability; Floods; Droughts; Climate Extremes	4
10	Climate Change; Causes; Modeling; Global Climate Models; Downscaling; IPCC Scenarios	4
11	Commonly used Statistical Methods in Hydro-climatology; Trend Analysis; EOF; PCA; CC; Statistical Downscaling	5
12	Ecological Climatology; Leaf energy fluxes; Plant canopies; Vegetation dynamics; Coupled climate vegetation dynamics; Carbon cycle climate feedbacks; Precipitation Recycling	4
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1		Nil
2		
3		
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10		
COURSE TOTAL (14 times 'P')		Nil

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

- Wallace, J.M., and Hobbs, P.V., *Atmospheric Science An introductory Survey*, International Geophysics Series, 2012

2. Bonan, G. B., Ecological Climatology, Cambridge University Press, 2002
3. Burde, G. I., Zangvil, A., The Estimation of Regional Precipitation Recycling. Part I: Review of Recycling Models. J. Climate, 14, 2497–2508., 2001.
4. Campbell, G. G. and Norman J. M., An Introduction to Environmental Biophysics, Springer, 1998
5. Von Stoeck and Zwiers F W, Statistical Analysis in Climatic Research, Cambridge, 1999
6. McGuffie, K. and Henderson-Sellers, A Climate Modelling Primer, Wilby, 2005
7. IPCC Assessment Report, 2013

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	Yes
19.2	Hardware	Yes
19.3	Teaching aides (videos, etc.)	Yes
19.4	Laboratory	Existing
19.5	Equipment	Existing
19.6	Classroom infrastructure	Yes
19.7	Site visits	No

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	0
20.2	Open-ended problems	10
20.3	Project-type activity	15
20.4	Open-ended laboratory work	0
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	Civil Engineering
2.	Course Title (<i>< 45 characters</i>)	MECHANICS OF SEDIMENT TRANSPORT
3.	L-T-P structure	2 - 0 - 2
4.	Credits	3
5.	Course number	CVL837
6.	Status (<i>category for program</i>)	PROGRAMME ELECTIVE

7.	Pre-requisites (course no./title)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	NIL
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	NIL

9.	Not allowed for (indicate program names)	
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course All Water Resources faculty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): 1. Mechanics of sediment transport has wide applications in river engineering and industry. 2. The river morphology is self-organized by the interaction between flow and the channel configuration. 3. It is important to predict river morphology formed under given conditions from viewpoints of flood protection, sustainable development of water resources, and high level of land planning. 4. The purpose of this lecture is to obtain knowledge on fluid mechanics, sediment transport, optimum design of hydraulic conveying systems and morphodynamics in rivers.	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Introduction; Equations of Particle Motion particle in a moving fluid, collision with the bed, diffusion of turbulence; Macroscopic View of Sediment Transport	
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	– bedload, suspended load; Threshold Condition for Sediment Motion – Critical stress for flow over a granular bed, Shields diagram; Mechanics of Bedload Transport: Bagnold hypothesis of bedload transport, bedload transport relations; Mechanics of Suspended Sediment Transport; Total load transport; Descriptive Analysis of Bedforms – introduction of bedform mechanics, dunes, antidunes, ripples, bars; Stability Analysis of Bedforms; Mechanism of transportation of materials by fluid flow through pipeline; Rheology and classification of complex mixtures; Fundamentals of two-phase flow; Phase separation and settling behaviour; Flow of non-Newtonian fluids through pipes: Turbulent flows of Complex mixtures, Slurry pipeline transportation, Design methods.
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15. Lecture Outline (*with topics and number of lectures*)

Module no.	Topic	No. of hours
1	Introduction	1
2	Equations of Particle Motion	1
3	Macroscopic View of Sediment Transport	1
4	Threshold Condition for Sediment Motion	1
5	Mechanics of Bedload Transport	1
6	Mechanics of Suspended Sediment Transport	2
7	Total load transport	1
8	Descriptive Analysis of Bedforms	1
9	Stability Analysis of Bedforms	1
10	Rheology and classification of complex mixtures	4
11	Fundamentals of two-phase flow: Phase separation and settling behaviour	5
12	Flow of non-Newtonian fluids through pipes: Turbulent flows of Complex mixtures, Slurry pipeline transportation, Design methods	9
COURSE TOTAL (14 times 'L')		28

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Design using field data to provide step-by-step computational procedures in solving practical river engineering and hydrotransport problems.	8
2	Experimental determination of viscosity and yield stress of slurries using rheometer	6
3	Bench scale testing of slurries to determine PSD, angle of repose, static settled concentration, unhindered and hindered settling velocities	6
4	Experimental measurement of sediment trapping efficiency of invert trap	4
5	Experimental measurement of velocity distribution using PIV	4
6		
7		
8		
9		
10		
COURSE TOTAL (14 times 'P')		28

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

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|-----|--|
| (1) | Chih Ted Yang, Sediment Transport, Theory and Practice, McGraw Hill, ISBN 0-07-114884-5, 1996. |
| (2) | Graf, W.H., Hydraulics of sediment transport, McGraw Hill, 1971. |
| (3) | Raudkivi, A.J., Loose Boundary Hydraulics, Pergamon Press, ISBN |

- 0-08-018771-4.
- (4) Ranga Raju and garde, R.J., Mechanics of sediment transport, Mcgra Hill, 1977.
- (5) M.Selim Yalin, Mechanics of Sediment Transport, Elsevier, 1977.

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	yes
19.2	Hardware	yes
19.3	Teaching aides (videos, etc.)	yes
19.4	Laboratory	Existing
19.5	Equipment	Existing
19.6	Classroom infrastructure	yes
19.7	Site visits	no

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	60
20.2	Open-ended problems	5
20.3	Project-type activity	15
20.4	Open-ended laboratory work	10
20.5	Others (please specify)	nil

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	Civil Engineering Department
2.	Course Title (<i>< 45 characters</i>)	GEOGRAPHICAL INFORMATION SYSTEM
3.	L-T-P structure	2 - 0 - 2
4.	Credits	3
5.	Course number	CVL838
6.	Status (<i>category for program</i>)	PROGRAMME ELECTIVE

7.	Pre-requisites (course no./title)	Nil
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	CEL455
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	CEL747

9.	Not allowed for (indicate program names)	Nil
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☒ 2 nd sem ☐ Either sem
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11.	Faculty who will teach the course Prof A. K. Gosain, Prof. A.K. Keshari and other WRE faculty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): 1. The major course objective is to develop an understanding of the theory behind the GIS. 2. To develop skills in the application of GIS to problems from a very large cross-section of areas.	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): What is GIS. Geographic concepts for GIS. Spatial relationships, topology, spatial patterns, spatial interpolation. Data storage, data structure, non-spatial database models. Populating GIS, digitizing, data conversion. Spatial data models, Raster and Vector data structures and algorithms. Digital Elevation Models (DEM) and their application. Georeferencing and projection systems, GIS application areas, Spatial analysis, quantifying relationships, spatial statistics, spatial search.	
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15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Definition of GIS, Why GIS is important? Contributing disciplines and technologies to GIS	2
2	Geographic concepts for GIS: Coordinate system, Representing earth digitally, Discrete Georeferencing, Global Positioning Systems, Projection system, Maps as representations of the world	3
3	Populating GIS: Creating digital data, digitizing and scanning, remote sensing and GPS as data source. Accessing existing data, data exchange, data conversion, transfer standards, Open GIS. Metadata.	3
4	Spatial data models: storing relationships, Raster and Vector GIS models	2
5	Spatial relationships: Connections and topology, spatial patterns, sampling the world, scale and geographic detail, uncertainty, spatial interpolation	3
6	Implementing geographic concepts in GIS: Fundamentals of Data storage, data structure, non-spatial database models	3
7	Vector data structures and algorithms. Storage of complex spatial objects. Storage of lines, polygons. Polygon overlay operation	3
8	Raster data structures and algorithms. Storage options for a raster data. Scan order. Decoding scan order.	3
9	Digital Elevation Models (DEM) and their application. Creation of DEMs, various functions on DEM.	3
10	GIS application areas: Spatial analysis. Combining data, map algebra, terrain modelling, quantifying relationships, spatial statistics, spatial search. Decision making in GIS context. Strategies for development implementation and management of GIS	3
11		
12		
COURSE TOTAL (14 times 'L')		28

16. Brief description of tutorial activities

NIL

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Introduction to ArcGIS	4
2	Geo-referencing and Digitization	4
3	Topology, Geo-Database	2
4	Database Management Systems: ER Diagram, SQL	4
5	Spatial Database Management Systems	4
6	Spatial Data Input and Editing: GPS	4
7	Introduction To Google Earth	2
8	Spatial Analysis: Interpolation and Buffering	2
9	Watershed Delineation	2
10		
COURSE TOTAL (14 times 'P')		28

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

1. Burrough, P. A., and McDonnell, R. A., Principles of Geographical Information Systems, 2nd Ed., Oxford University Press, 1998
2. Demers, M. N., Fundamentals of Geographic Information Systems, 3rd Ed., John Wiley & Sons, 2002
3. Longley, P. A., Goodchild, M. F., Maguire, D. J., and Rhind, D. W., Geographic Information Systems and Science, 2nd Ed., John Wiley and Sons, 2005
4. Kang-tsung Chang, "Introduction to Geographic Information Systems", McGraw-Hill Book Company, 2006
5. Ramez Elmasri, Shamkant B.Navathe, "Fundamental of Database Systems", Pearson Addison Wesley, 2003
6. Bailey T C, Gatrell A C, 1995, Interactive spatial data analysis, Harlow, Longman/New York, John Wiley & Sons Inc.
7. Bonham-Carter G F, 1994, Geographical information systems for geo-scientists: modelling with GIS, New York, Pergamon Press
8. Hearnshaw H M, Unwin D J (eds.), 1994, Visualisation in geographical information systems, Chichester, John Wiley & Sons
9. Isaaks E H, Srivastava R M, 1989, Applied geostatistics, Oxford University Press.
10. Longley P A, Goodchild M F, Maguire D J, Rhind D W (eds.), 1999, Geographical information systems: principles and technical issues, 2nd Ed., John Wiley & Sons Inc.
11. Maguire D J, Goodchild M F, Rhind D W (eds.), Geographical information systems: principles and applications, Harlow, Longman/New York, John Wiley & Sons Inc., 1991.
12. Masser I, Blakemore M (eds.), Handling geographic information: methodology and potential applications, Harlow, Longman/New York, John Wiley & Sons Inc., 1991.
13. Muller J C, Lagrange J P, Weibel R (eds.), GIS and generalisation: methodological and practical issues, London, Taylor and Francis, 1995.

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	Yes
19.2	Hardware	Yes
19.3	Teaching aides (videos, etc.)	No
19.4	Laboratory	Existing
19.5	Equipment	Existing
19.6	Classroom infrastructure	Yes
19.7	Site visits	No

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	10
20.2	Open-ended problems	5
20.3	Project-type activity	10
20.4	Open-ended laboratory work	10
20.5	Others (please specify)	20 for group work over the semester

Date: 12-02-2015

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department /Centre proposing the course	Civil Engineering
2.	Course Title (<i>< 45 characters</i>)	HYDROLOGIC APPLICATIONS OF REMOTE SENSING TECHNOLOGY
3.	L-T-P structure	2 - 0 - 2
4.	Credits	3
5.	Course number	CVL839
6.	Status (<i>category for program</i>)	PROGRAMME ELECTIVE

7.	Pre-requisites (course no./title)	NIL
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	NIL
8.2	Overlap with any UG/PG course of other Dept./Centre	NIL
8.3	Supercedes any existing course	CEL748

9.	Not allowed for (indicate program names)	NIL
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10.	Frequency of offering	☐ Every sem ☐ 1 st sem ☐ 2 nd sem ☒ Either sem
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11.	Faculty who will teach the course Prof. A. K. Keshari, Prof. A.K. Gosain and other WRE faculty	
12.	Will the course require any visiting faculty?	No

13.	Course objective (<i>about 50 words</i>): 1. To understand the interaction of electromagnetic interaction with matter and working of aerial and satellite remote sensing and radar 2. To learn image interpretation and satellite image processing 3. To learn to make use of aerial and satellite data for applications in hydrology, water resources, agriculture, geology, environment and snow & glacier studies 4. To learn to integrate remote sensing and GIS analysis	
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14.	Course contents (<i>about 100 words</i>) (<i>Include laboratory/design activities</i>): Principles of remote sensing, Remote sensing platforms and data acquisition systems, Wavebands, Radiometric quantities, Spectral reflectance and spectral signature, Interaction of electromagnetic radiation with land surface features, hydrosphere and atmosphere, Data capture for simulation of land surface processes, Photographic and image interpretation, Satellite image	
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	processing, Earth surface features inventory, Geomorphology, Landuse classification, Landuse planning and landcover mapping, Flood plain mapping and flood plain zoning, Remote sensing applications in water resources, agriculture, geology and environmental monitoring, Applications in snow and glacier studies, Snow line, Ice cover, Snow-pack properties, Integrated use of remote sensing and GIS, Database preparation and Decision support analysis, Estimation of damages due to hydrologic extremes and preparation of contingency plans, Case studies
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15. Lecture Outline (*with topics and number of lectures*)

Module no.	Topic	No. of hours
1	Principles of remote sensing, Remote sensing platforms and Data acquisition system, Wavebands & radiometric quantities, Spectral reflectance and spectral signature	4
2	Integration of electromagnetic radiation with land surface features, hydrosphere and atmosphere, Data capture for simulation of land surface processes	2
3	Photographic and image interpretation and Satellite image processing	4
4	Earth surface features inventory and Geomorphology,	2
5	Landuse classification, Landuse planning and landcover mapping	2
6	Flood plain mapping and Flood plain zoning	1
7	Remote sensing applications in water resources, agriculture, geology and environmental monitoring	4
8	Applications in snow and glacier studies, Snow line, Ice cover and Snow pack properties	2
9	Integrated use of remote sensing and GIS	2
10	Database preparation and Decision support analysis	1
11	Estimation of damages due to hydrologic extremes and preparation of contingency plans	1
12	Case studies	3
COURSE TOTAL (14 times 'L')		28

16. Brief description of tutorial activities

NA

17. Brief description of laboratory activities

Module no.	Experiment description	No. of hours
1	Introduction to Basic Digital image processing softwares	2
2	Georeferencing and Co-registering of satellite images	2
3	Interpretation of Satellite Images	4
4	Image Classification	4
5	Geomorphological analysis	2
6	Field Spectroscopy	2
7	Spectral Indices	2
8	Multispectral and hyperspectral image processing	2
9	Applications in snow and glacier studies	4
10	Flood plain mapping, Flood plain zoning and other hydrological, agricultural and environmental applications	4
COURSE TOTAL (14 times 'P')		28

18. Suggested texts and reference materials

STYLE: Sonntag, R. E., Borgnakke, C., and Van Wylen, G. J., *Fundamentals of Thermodynamics*, 5th Ed., John Wiley, 2000.

- (1) Lillesand, T., Kiefer, R. W., Chipman, J., *Remote Sensing and Image Interpretation*, 6th Ed., Wiley, 2007.
 (2) Curran, P.J., *Principles of Remote Sensing*, ELBS, 1988
 (3) Rees, W.G., *Physical Principles of Remote Sensing*, 2nd Edition, Cambridge

University Press, 2001.

(4) Keshari, A.K., Satellite Remote Sensing, Ane Books, 2015

(5) Keshari, A.K. and Singh, R.P., Use of microwave radiometry for monitoring the alpine environment. Snow, Hydrology and Forests in High Alpine Areas, IAHS Publ. No. 205, 81-89, International Association of Hydrological Sciences, 1991.

(6) Ambast, S.K., Keshari, A.K. and Gosain, A.K., An operational model for estimating regional evapotranspiration through surface energy partitioning (RESEP). International Journal of Remote Sensing, 23(22): 4917-4930, 2002.

19. Resources required for the course (*itemized & student access requirements, if any*)

19.1	Software	Yes
19.2	Hardware	Yes
19.3	Teaching aides (videos, etc.)	Yes
19.4	Laboratory	Yes
19.5	Equipment	Yes
19.6	Classroom infrastructure	Yes
19.7	Site visits	Yes (preferable)

20. Design content of the course (*Percent of student time with examples, if possible*)

20.1	Design-type problems	25
20.2	Open-ended problems	15
20.3	Project-type activity	30
20.4	Open-ended laboratory work	30
20.5	Others (please specify)	

Date:

(Signature of the Head of the Department)