HYDROLOGICAL EDUCATION AND TRAINING

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INTRODUCTION

The hydrologic cycle under the driving force of the Sun is a continuous process by which water is transported from the oceans to the sea. It extends across a wide spectrum of space and time scales and through the storage and release of latent heat accompanying phase change, it affects the global circulations of atmosphere and ocean, in turn affecting weather and climate. Due to water's properties as a solvent, the hydrological cycle is not only the integrating process for the fluxes of water and energy but also for some chemical substances. The vital role of water in the evolution and operation of Earth's system provides the rationale for hydrology being considered as a geoscience. Its aim is to investigate and understand natural phenomena as opposed to mere solutions of various adhoc engineering, agricultural and other water related problems. Hydrology is thus an earth science, which encompasses the occurrence, distribution, movement and properties of the waters of the earth and their environmental relations. It interfaces with allied fields of geology, climatology, meteorology, oceanography and glaciology. It has not only to deal with complex processes of the natural hydrological cycle, but also influence of man's activities and intervention in almost every aspect of hydrological cycle.

The main motivation for the study of hydrology in the past was to improve technologies for the development of water resources. It has tended to follow problem solving approach of engineering profession, relying on mathematical analysis of data (observations) usually made by other persons and often for other purposes. The application of established principles of natural sciences, thus remained in background and solution of hydrological problems were usually approached in an empirical way. Recently, under the impetus of concern for global change, has led to increased emphasis on development of technologies on a sound scientific basis. While the approach as a applied subject requires broad based undergraduate training followed by specialisation at graduate level, the professional scientific approach demands specialisation at the undergraduate level. Nash et al (1990) have examined in detail various aspects of the education of hydrologists. While stating the major inadequacies of present day hydrology as (a) methodological deficiencies, (b) the slowness and unevenness of the advance of scientific knowledge of hydrology through research, and (c) the slow diffusion of knowledge from research to practice, the authors have listed the following aims and content of education in hydrology at the university level:

(a) To develop and improve awareness of the totality of interconnected (mainly physical) processes involved in the hydrological cycle;

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(b) To provide the maximum possible training in relevant areas of the basic scientific disciplines underpinning hydrology;

(c) To develop the connections between those basic disciplines and the scientific study of various hydrological processes;

(d) To develop more fully and clearly the connections between scientific knowledge of hydrologic processes and the current (and potentially improved) professional practice of hydrology.

The International Hydrological Decade (1965-75) was launched by the General Conference of UNESCO at its Thirteenth Session to promote international cooperation in the field of hydrological research and education as a means for achieving a fuller assessment of the world's water resources and their more rational use. In 1972, the General Conference decided to continue and develop the basic objectives of the Decade within the frame work of a long term International Hydrological Programme which started in 1975. This provided a strong impetus for growth of hydrological education and a number of postgraduate courses in hydrology and in water resources development were instituted at a number of universities throughout the world, with the support and sponsorship of UNESCO and WMO.

Chandra and Seth (1975) have categorized the different levels of hydrological education and training which have been broadly classified under three categories:

(i) Hydrological technicians and auxiliary personnel,
(ii) Professional Hydrologists,
(iii) Research hydrologists

Hydrological technicians conduct measurements and process observed data applying standard techniques, while the auxiliary personnel (observers) maintain instruments and field stations and take observations. The professional hydrologists or hydrological engineer studies hydrological phenomena relevant to the planning, design, construction and operation of water resources projects and carries out necessary analysis and design. The role of research hydrologist is to develop new techniques of observation, analysis and design as well as to undertake basic studies of a scientific nature.

REVIEW OF LITERATURE

India with a geographical area of 329 million ha is blessed with large river systems, variety of climatic and physiographical conditions, seasonal variability of monsoon rainfall in space and time, and has to cater to growing demands of increasing population. There are constraints on the extent to which water resources could be utilized. With the advent of five year plans, after independence, there has been significant progress in development of country's water resources. Hydrology is an indispensable requirement for design and planning of water resources and as such there have been corresponding developments in application of hydrology. Facilities have been created for in service training and hydrology education at different levels. The status and achievements as well as contributions in technical journals and proceedings dealing with hydrological education and training in India since independence have been reviewed and discussed in the following paras.

Chandra and Seth (1975) suggested an integrated scheme for the teaching of hydrology at all levels viz. for technicians and junior hydrologists at I.T.I. and diploma level, generalists in hydrology at undergraduate level and specialists in hydrology at post-graduate level. It was mentioned that the University level, there are four categories of facilities available in different countries: (i) complete undergraduate education of professional hydrologists, (ii) hydrology as a subject of study in education in related fields such as hydraulics, sanitary, water resources, environmental and agricultural engineering, geology, geography and geophysics, etc., (iii) Hydrology as a major option in undergraduate or postgraduate curricula, and (iv) post graduate education to train professional hydrologists. The authors proposed a four year integrated programme of study consisting of 48 units for Bachelor of Engineering (Hydrology) degree having 6 and half units of humanities, 14 units of basic sciences, 10 and half units of engineering sciences, 10 units of hydrological sciences and 7 units of applied engineering.

Rao (1975) emphasized the need for introduction of hydrology and water resources subjects with emphasis on modern developments in the undergraduate and post-graduate courses in the Civil Engineering curriculum. The author suggested restructuring of the existing Bachelor's programme in Civil Engineering and the Master's programme in hydraulics to include specialization in these subjects. It was stated that the electives, and the minor and major projects provide sufficient room to introduce specialization in hydrology at B.E. (Civil) level, and a half unit course in hydrology as a compulsory subject and a one unit course in advanced hydrology as an elective subject. At the post-graduate level relevant subjects for hydrology and water resources were recommended viz. advanced hydrology, flood control, groundwater engineering, hydrometeorology, geophysical investigations, water resources planning, economics and management, water resources systems engineering, and environmental engineering.

Sikka (1975) emphasized the need to have realistic courses having practical applications in water and land use resources, emphasising 'total management of water' and specialisation for dealing with variety of climatological and hydrological conditions at regional and national levels.

Narain (1984) discussed the role of World Bank in education and training in water management. He mentioned about preliminary estimate indicating recruitment of 500 degree holders and 2000 diploma holders every year in irrigation departments of various States and recommended suitable changes in curricula by providing more weightage to irrigation related subjects at degree/diploma level in Civil Engineering. At post-graduate level, the author mentioned about setting up of advanced courses in water management at University of Roorkee, Anna University and M.S. University, Baroda. In the training area, the author mentioned about setting up of water and land management institutes, starting with WALMI at Aurangabad in 1980. The author advocates that the training programmes in water management should focus on irrigation methodologies with a view to improve irrigation efficiency at the farm level.

Singh (1984) mentions about establishment of the Thomson College at Roorkee in 1847 to train engineers and diploma holders for the Ganga Canal system and other irrigation systems then being built in the country. This tradition has been continued at University of Roorkee and the subject of irrigation engineering had had an important

place in B.E. Degree programme in Civil Engineering at the University. The first post-graduate course in Hydraulic Engineering was started at Roorkee in 1954 with primary stress on fluid mechanics but also having components of hydrology and irrigation. The Water Resources Development & Training Centre was established in 1955 and has trained a large number of engineers including those from countries outside India. In 1980, Master's level programme in water use management was introduced, the first in the country.

Subramanyam (1984) discussed the need to introduce water management engineering courses in Universities and suggested educational requirements for a cadre consisting of three tiers, viz. (i) field level staff, (ii) supervisory staff, (iii) class II and I officers. The author also suggested coverage of specific topics from civil engineering, mechanicam engineering, agriculture and general areas. Suggestions were also made for refresher courses and special courses of appropriate content and duration depending upon the need and level of personnel.

Varma and Sinha (1984) described and discussed the role of Water Resources Development Training Centre (WRDTC) established in 1955 at University of Roorkee, in education and training in irrigation water management. The authors also mentioned about a Master's level course in water use management which was started at WRDTC in year 1980-81, having coverage of various topics like computer programming and numerical methods, irrigation system design, hydrology, soil science, agronomy, irrigation project management, farm irrigation practice, ground water development, system design technique, economics, land drainage and reclamation, etc.

UNESCO (1986) provides information on the international post-graduate courses sponsored by UNESCO within the frame work of the International Hydrological Programme. This includes two courses in India, viz. (i) International Post-Graduate Diploma and Master's Course in Hydrology at Department of Hydrology, University of Roorkee, and (ii) International Post-graduate Diploma Course in Hydrology and Water Resources Engineering at the Centre for Water Resources, Anna University, Madras. The course at Roorkee provides for specialization in surface water hydrology, ground water hydrology, and watershed management.

Dasgupta (1988) identified the need for distance mode regular and continuing engineering education. The author recommended a systems approach for identification of educational needs, the characteristics of the learners, their background, experience, maturity, aspirations, motivation, past failures, previous knowledge and the gap in their education. Various advantages of distance education were listed and it was stressed that distance education with its complimentary and supplementary roles in engineering education would soon emerge as appropriate education system.

Chopane et al (1988) emphasised creation of an environment and culture in employment sector and in technical education sector so as to promote life long education, aiming ultimately at continuously learning society to facilitate the engineering personnel to achieve excellence. The authors also listed various challenges in technical manpower planning and development, viz. (i) to estimate the manpower requirement in various sectors realistically, (ii) to mobilize resources to develop the manpower force, (iii) to train them time and again to adopt to changes and avail

opportunities, and (iv) to create congenial environment to foster industrial growth and development.

Koshal (1988) described various developments in audio-visual media such as computer aided learning, television/video text and audio text for use as a multi-media approach to mass and effective learning.

Lal and Raj (1988) recommended the correspondence courses as a viable alternative for imparting engineering education economically and conveniently. The limitations of AMIE examination system of the Institution of Engineers was analysed and a strategy for developing and effectively implementing a correspondence course for engineering degree course was presented. It was suggested that the correspondence courses should be prepared and monitored through three tier system of centres, viz. lead centres, regional centres and nodal centres. The authors also suggested various measures to ensure the effective implementation of correspondence courses, viz. (i) responsibility of practical training, (ii) introduction of courses on enterpreneurship development, (iv) periodic review/revision of syllabus, (v) strengthening of evaluation system, (vi) inclusion of continuing education programme, etc.

Thanikachalam (1988) proposed a model for operating the open University courses in Engineering consisting of four distinct stages based on systems approach to curriculum development, viz. (i) planning, (ii) development, (iii) implementation, and (iv) evaluation and revision.

Char and Suryanarayana (1989) discussed the education and training requirements in various disciplines and levels in water resources upto year 2025. The training of personnel in the water resources sector was envisaged at three stages, viz. induction at entry, in service for middle level and appreciation/management for senior level officers. The authors also mentioned about dispersed and somewhat disorderly status of education and training programs and highlighted the need to close the gap between course contents and field requirements. The need for providing proper weightage to: (i) environmentally sound management, (ii) management technology in general, (iii) use of computers, (iv) construction management, and technology, (v) water laws and legislature processes, (vi) demand, use and conservation of water, (vii) economic and demographic considerations, (viii) interdisciplinary approach and conflict, (ix) institutional constraints and funding, etc. was also stressed.

Chawla and Changkakati (1989) emphasized the role of continuing training for professionals in water resources to keep abreast of new technologies. The status of degree and non-degree education and training in water resources in India was also presented. The authors have recommended proper coordination and interaction between educational, research and field organisations for proper professional development in water resources sector. Post graduate training, induction training and continuing education programs were also suggested for professionals at all levels.

Garde (1989) has discussed some of the problems associated with teaching of hydraulic engineering and water resources. The author has recommended constitution of committee of experts to examine the status of research and suggest action for

using findings of research in teaching so as to improve design technology. The use of audio-visual aids for this purpose is also suggested.

Krishna Murthy (1989) strongly advocates the use of computers by the water resources professionals and acquiring adequate proficiency for this purpose by training and education, so as to keep pace with the advancements in science and technology. The author also recommends for availability and development of software and interconnection of computers in different locations for easy access and increased efficiency in planning, design and management of water resources projects.

Padhye (1989) made a detailed review of Indian experience in transfer of knowledge from developed countries to India in post independence period. Since achieving independence in 1947, India has made considerable strides in water resources development and various large multipurpose projects have been built over last 45 years. Simultaneously, technological upgrading has also been taking place over these years. Central Board of Irrigation and Power created in 1927, creation of Central Water Commission, strengthening of Central Water and Power Research Station, Khadakwasla were important steps in this direction. The training programmes under the point four and Colombo Plan programmes of the fifties, Bilateral programmes of technical assistance such as the Indo-French, Indo-German, Indo-USSR and also training at USBR, TVA, Corps of Engineers, USA, all contributed to development of expertise in fifties and sixties. Important contributions have also been made in the training effort by the UN agencies such as UNDP, WMO, UNESCO, FAO and others. DANIDA, SIDA, USAID and Ford Foundation have also contributed significantly in this effort in recent years. The World Bank has helped in establishment of Water and Land Management Institute in States. The author has also mentioned about developments in engineering education, particularly establishment of Indian Institutes of Technology's with assistance from U.K., U.S.A., U.S.S.R., and Federal Republic of Germany. It is recommended that indepth evaluation of training programme should be made to decide future course of action, and there should be greater interaction between developing countries.

Rao (1989) stressed the importance of inservice training programme in Hydrology to supplement university education through exposure to inter-disciplinary approach and to introduce new developments in the expanding fields of activity in any organisation. It was suggested that the course material for such courses should be tailored to suit the immediate and future requirements, and should be presented in a manner so as to be challenging, instructive and enjoyable. The author recommended coverage of topics like water resources, meteorology, precipitation, interception, evaporation and transpiration, infiltration, flood runoff, flood routing, extreme events analysis, catchment yield and storage, snow hydrology, water quality management, environmental impacts and safeguards, water resources systems, etc. It was emphasized that the methodology for hydrologic analysis has to be specially tailored to suit: (i) the objective - decides the tolerances acceptable, which in turn decide the desirability and of employing sophisticated tools within the time frame available for analysis, and (ii) the data situation - governs the achievable tolerance limits and the appropriateness/usefulness of methodology available/evolved.

Hydrological knowledge transfer activities from developed countries to developing countries like India have to be planned keeping in view various local conditions

and socio-political structure. This aspect has been discussed by Seth (1989) and the desirability of creation of a nuclei of competent personnel and teaming together of developer and user in a research team has been emphasized. For the success of such approach, the author has cited the establishment of National Institute of Hydrology as a UNDP assisted project and transfer of SHE model technology to NIH through a project funded by the Commission of European Communities.

Reddy (1989) mentioned about guideline set in National Water Policy for providing standardised training to personnel engaged in the water resources sector. Hydrology was considered as an important area for project conception, investigation, planning and formulation. The author also mentioned about good capacity developed in India to train the personnel in different disciplines through various organisations and institutes by way of formal education, refresher courses, workshops, seminars, study tours, etc.

Sharma and Sharma (1989) dealt with the needs and status of education and training in ground water hydrology. The various areas of ground water hydrology requiring R & D effort were identified by the authors. These include: (i) evaluation of norms, under varying hydrogeological conditions for various inputs and outputs for the water balance equations, (ii) environmental effects of development of ground water, (iii) conjunctive use of surface and ground water, (iv) artificial recharge, (v) saline and fresh water inter face problems, (vi) monitoring of chemical quality of ground water, (vii) evaluation and exploitation of geothermal waters, (viii) construction of adequate types of ground water structures, and reclamation of sick wells. The authors stressed the need for specifically oriented educational or training courses for development of special talent and expertise to tackle these problems. An interaction between universities and technical institutions which produce the trained manpower and the professional bodies which employ these personnel, was also recommended. A scheme for inservice training of officers of water resources organisation proposed by Dr. Jagdish Narain was also suggested for implementation. It includes: (i) induction training of 12 months on entry to service, (ii) specialist courses of 2-3 months after 3 years of service, (iii) specialised training of 6-12 months between 8-12 years of service, (iv) advanced specialist training of 1 month and refresher course in field of specialisation of 4 months to 1 year duration after 3-5 years of specialised training, (v) appreciation training of 4 months to 1 year after 15-20 years of service and, (vi) management training for senior executives of 1 to 6 months after 20 years of service.

Swamy (1989) reviewed the developments in hydrology and water resources education in different parts of world in general and India in particular. The author mentioned about UNESCO sponsored P.G. and Master's courses at University of Roorkee and Anna University, for inservice personnel, two year M.Sc. Hydrology course of Andhra University, One year P.G. Diploma and Two year degree courses at IIT's and Engineering Colleges providing possibility of studying various hydrological and related subjects. A three year M.Sc.(Tech) degree course in Hydrology and Water Resources was proposed to provide coverage for topics like engineering hydraulics, systems analysis in water resources, etc. for starting initially at two Indian Universities.

Chandra et al (1991) reviewed existing programmes of education and training for drought management and suggested curricula for: (i) on the job training of technicians, and (ii) professional and short duration training courses for supervisory

personnel, curricula for specialized short duration courses for training of managers were also suggested. Various topics proposed for training programme included: (i) drought survey, (ii) drought management, (iii) drought proofing, (iv) data collection and storage, (v) agricultural statistics, (vi) water conservation - field technique (vii) socio-economic surveys, (viii) data monitoring and low flow analysis, (ix) prediction and control of drought, (x) long range forecasting and control, (xi) integrated data base management system for drought studies, (xii) application of remote sensing techniques for drought monitoring, (xiii) reservoir operation with carryover storage, (xiv) water conservation, (xv) low flow modelling and forecasting, (xvi) drought response plan, (xvii) water conservation management, (xviii) drought proofing systems, (xix) International cooperation for decision making for drought mitigation, (xx) climate change and drought management.

It is seen that there have been relatively less attempts towards providing ideas and proposals for rationalisation and improvement in hydrological training and education at various levels. There have been some suggestions for introduction of under-graduate programmes but faced with constraint of absence of cadre development policies at Government level in this area. Post graduate education in hydrology is generally thought of as training for inservice sponsored personnel or providing some knowledge of hydrology as electives under general civil engineering and water resources programmes. Some attempts have been made in quantifying education and training requirements upto year 2025. Correspondence courses, refreshers courses, distance education and computer related education and training have been mentioned by authors as of relevance in water resources and hydrology. Though some encouraging developments have taken place with creation of hydrology cells in some States, a clear cut policy for hydrological education and training, keeping in view needs of personnel at different levels and cadre development plans are yet to emerge.

UNESCO's PROGRAMME IN HYDROLOGICAL EDUCATION

Gilbrich (1991) has highlighted the achievements of 25 years (1965-1990) of UNESCO's programme in hydrological education under IHD/IHP which included over fifty meetings, two dozen publications, more than a hundred experts participants in working groups and panels and about ten thousand people who have undergone a training programme. It is mentioned by the author that before the International Hydrological Decade started in 1965, hydrology was at the threshold of becoming an independent subject. In the University curricula some hydrological material was covered as part of water resources development subjects, such as irrigation and hydraulics or as part of courses in physical geography and geomorphology. The UNESCO's coordinating council created a working group on Education and Training of Hydrologists with following terms of reference:

(a) Study information on education of hydrologists in different country and recommend effective programmes of education for hydrologists and syllabi and to make recommendations concerning them;

(b) Consider existing text books and other publication in various languages and to recommend suitable ones for translation and use in different areas, or to propose the preparation of new text books;

(c) Consider and recommend typical education material for use in field training as well as in institutional training;

(d) Consider possible measures to improve teachers qualifications, including the organization or periodical seminars;

(e) Present at an early session of the Council, a report containing proposed actions of the Council in the whole of field of education and training of hydrologists.

At the beginning of IHD, a few post graduate programmes in hydrology had already started in some countries. The activities and support provided by UNESCO led to crystallization of thinking on subject matters of hydrological education, methodology in teaching hydrology, text books on hydrology, teaching aids, curricula and syllabii, international courses, introduction of modern developments and new subjects, education at undergraduate level, continuing education, visual aids, technician training, training of experts, training of teachers and supervisors, etc.

POST GRADUATE EDUCATION AND TRAINING IN INDIA

The post graduate education and training in Hydrology and Water Resources in India since independence has progressed remarkably well. Some of the notable developments are briefly described as follows:

(1) Water Resources Development Training Centre at University of Roorkee in 1955

The Department of Civil Engineering of the University of Roorkee is the oldest and probably the largest Civil Engineering Department in the country. It was started on 19th October 1847 under the name of Thomason Engineering College which became full fledged University in the year 1949. The department has made significant contributions in the areas of water resources and irrigation engineering both at undergraduate and postgraduate levels. The subject of hydrology was included int he post graduate course of Dam Design/Irrigation Engineering and Hydraulics in fifties, and later on introduced as a subject at undergraduate level as weli.

The Government of India with the assistance of ECAFE, UNDP and USAID established this unique center on November 25, 1955 at the University of Roorkee. During the last 36 years, the WRDTC has established itself as a centre of excellence in the engineering and irrigation water management. It has so far provided post graduate education to 1107 serving professionals from Irrigation and Power Sectors from within the country and to 498 officers from 34 other countries of Asia, Africa, Latin America and the Far East. It has provided an excellent opportunity to engineers from India and abroad for training as well as exchange of knowledge and experience. The centre offers post graduate diploma and Master's degree programmes in Water Resources Development and Irrigation Water Management. The subject matter coverage includes topics related with hydrology as well as irrigation, water use management, flood control, river engineering, ground water, hydropower, construction plant and machinery, etc. A notable feature of the training programme

of the centre is the visits to Water Resources Projects. WRDTC has also made significant contributions through Doctoral Research and sponsored and collaborative research projects in various aspects of water resource development and management (W.R.D.T.C., 1991-92).

(2) UNESCO sponsored International P.G. Hydrology Course at University of Roorkee

With a view to strengthening training activities in hydrology in developing countries and for transfer of educational activities to such areas, UNESCO initiated the opening of an International Post Graduate Course at the School of Hydrology, University of Roorkee in year 1972. It was the first such course in Hydrology in a developing country. The School of Hydrology has not became a full fledged Department of Hydrology and offers the following academic programmes:

(1) Postgraduate Diploma in Hydrology (12 months duration)

(2) Master's Degree in Hydrology (additional duration of four and half months after completion of P.G. Diploma)

These courses are sponsored by Government of India, UNESCO, I.D.R.C. Canada and the Royal Government of the Netherlands. The WMO also sponsors participants to the course. The Government of India provided funds for the buildings and other facilities and U.P. Government is bearing the entire recurring expenditure. The Department has also acquired modern hydrologic equipments through UNESCO and UNDP. The UNESCO, UNDP and Ford Foundation provided specialists for lectures under consultancy assignments. At the P.G. level the trainees have the option for specialising in one of the following areas:

(i) Surface water hydrology;
(ii) Ground water hydrology;
(iii) Watershed Management

Master's programme provides option for either a dissertation work or a course work of one semester. The subjects covered include advanced topics not included at P.G. level. Facilities have also been created for research work leading to Ph.D. Degree. The department over the years established expertise and facilities not only for education and training at post graduate diploma and master's degree level, but also for Ph.D. programmes in a number of areas. The courses covered at P.G. level include:

(A) Compulsory Subjects:

1. Hydrologic elements and analysis (1 unit), 2. computer methods (1/2 unit), 3. Hydrometeorology (1/2 unit), for surface water specialisation or hydrogeology (1/2 unit) for ground water specialisation, 4. Probability and statistics in hydrology (1/2 unit), 5. Channela dn fluvial hydraulics (1/2 unit), 6. Mathematics (1/2 unit), 7. Water resources planning and management (1/2 unit), 8. Water quality and environment (1 unit), 9. Stochastic hydrology (1/2 unit), 10. Remote sensing applications in hydrology (1/2 unit) or Forest and agricultural :hydrology (1/2 unit)

(B) Optional Subjects:

1. For Surface Water Specialisation - (i) Geohydrology (1 unit), (ii) Systems Analysis and surface water planning (1 unit), (iii) Parametric hydrology (1/2 unit);

2. For Ground Water Specialisation - (i) Ground water hydrology (1 unit), (ii) System analysis and ground water systems (1 unit), (iii) Geophysical investigations (1/2 unit);

3. For Watershed Management Specialisation: (i) Planning and management of watershed (1 unit), (ii) Watershed behaviour and conservation practices (1 unit), (iii) Systems ecology and environmental planning (1/2 unit).

The subject areas for which facilities are provided to select any four as electives in a four and half month semester for Masters course include: physical hydrology, models and analogs, nuclear methods in hydrology, stochastic processes, integral transforms, water resources economics, water use and management; forest and agricultural hydrology, urban hydrology, flood forecasting, legal aspects in hydrology, groundwater flow, drainage engineering, hydrogeology of hard rocks, sub-surface investigations, hydrogeochemistry, conjunctive water resources planning, geomorphology, remote sensing hydrology, snow hydrology and water quality modelling.

The training programme of the course has been designed to equip the participants with the modern development in hydrology and its application to rational planning for water resources development. The training at the course builds up sufficient competence in data collection and analysis, using latest techniques in hydrologic design and planning. The syllabii of the course have been constantly under review and changes are incorporated to include latest developments keeping in view the requirements of the sponsoring agencies.

In view of the large scale economic developments in the head water reaches of the basins, watershed management has achieved considerable importance. The development plans in these areas have to be based on integrated watershed resources development approach. The watershed management specialisation takes care of this aspect.

The training programme at Master's level included lectures, course work, laboratory work, seminars, study tours and specialist lectures. Each trainee is required to prepare a detailed project report towards the end of the course.

To develop curricula and training facilities to faculty in six specialised fields and laboratory facilities at the School, an UNDP project was sanctioned by the Government to the School with a provision of U.S. $ 4.22 lakhs. Under this project faculty was trained in the areas of watershed hydrology, hydrologic systems, snow hydrology, remote sensing hydrology, water quality modelling and operational hydrology. The project had three components - training, consultants and equipment. Equipment worth U.S $ 2.16 lakhs were procured to develop training programme and scientific research activities in an integrated manner and thereby strengthen the teaching and research programmes (D.O.H., 1992).

Since its inception, during period 1972-1991, it has trained 456 officers at P.G. level including 287 from India and 359 officers at Master's degree level including 246 from India. Foreign trainees have have come from 29 countries of Asia and Africa (Table 1). There has been significant contribution through research studies for Master's dissertation by 176 serving engineers and scientists covering a wide variety of hydrological problems. The department has also organised nineteen short term courses, four workshops and three symposia as well as contributed through research and consultancy projects and doctoral research programmes (D.O.H., 1991-92).

(3) UNESCO Sponsored International P.G. Course in Hydrology and Water Resources Engineering at Anna University, Madras

The Centre for Water Resources at Anna University, Madras offers two post-graduate/degree courses of 1 year/1 and half year duration in the areas of hydrology, water resources engineering and irrigation water management. The course is also sponsored by UNESCO, and is the second course of its kind in the country.

The course is designed for inservice engineers and scientists to cater for the needs of African and Asian countries aiming to increase the working knowledge of persons involved in the assessment and utilisation of water. A fairly comprehensive knowledge of basic principles of hydrology and integrated planning for development and management of water resources is imported through lectures, tutorials, laboratory work, field visits, seminars, and projects.

(4) Other Post Graduate Programmes

The Institutions like IIT's at Kharagpur, Delhi, Kanpur, Bombay and Madras; Andhra University, Waltair, Bihar College of Engineering, Patna; M.R. Engineering College, Jaipur and a number of engineering colleges and Agricultural Universities also provide facilities for post-graduate programmes with emphasis on the subjects dealing with the areas of water resources and water management as well as hydrology, with the coverage/emphasis of subjects differing from place to place. The regular Master's degree courses in Civil Engineering at some of the engineering colleges also have coverage of hydrology and related subjects. The Punjab Engineering College, Chandigarh has been running a post-graduate programme in Irrigation and Hydraulics since 1963 covering the subjects of advanced hydrology, groundwater engineering, water resources planning and systems, open channel flow and sedimentation, irrigation and drainage design, etc. for regular students as well as in-service engineers sponsored by Punjab and Haryana Irrigation Department (P.E.C., 1992).

Table : 1 Participation During 1972 to 1991 in P.G. and M.E. Programmes at Department of Hydrology, University of Roorkee, Roorkee - 247 667

From Foreign Countries		P.G.	M.E.
1.	Afghanistan	16	8
2.	Bangladesh	11	7
3.	Burma	2	-
4.	China	2	2
5.	D.P.R. Yemen	4	2
6.	Ethiopia	1	1
7.	Ghana	3	3
8.	Indonesia	22	19
9.	Iran	12	7
10.	Iraq	2	2
11.	Jordan	1	1
12.	Malaysia	2	2
13.	Morocco	1	1
14.	Nepal	16	15
15.	Nigeria	3	2
16.	Pakistan	1	-
17.	Palestine	1	1
18.	Panama	1	1
19.	P.D.R. Laos	4	2
20.	Philippines	10	4
21.	Somalia	1	-
22.	Sri Lanka	11	7
23.	Sudan	10	7
24.	Syria	4	1
25.	Tanzania	5	4
26.	Thailand	4	2
27.	Uganda	2	-
28.	U.A.R. (Egypt)	2	-
29.	Vietnam	15	12
	Total	**169**	**113**

From Indian States/ Organisations		P.G.	M.E.
1.	Assam	53	47
2.	Andhra Pradesh	8	6
3.	Arunachal pradesh	5	4
4.	Bihar	13	12
5.	CSWCRTI	2	1
6.	CWC	13	13
7.	CGWB	1	1
8.	DVC	4	3
9.	Goa	4	4
10.	Gujarat	19	17
11.	Himachal Pradesh	4	1
12.	Jammu & Kashmir	6	6
13.	Karnataka	20	16
14.	Kerala	5	4
15.	Madhya Pradesh	21	17
16.	Maharashtra	12	12
17.	Manipur	1	1
18.	Ministry of Agri.	1	1
19.	Mizoram	1	1
20.	NIH	2	2
21.	Orissa	43	35
22.	Punjab	1	1
23.	Tamil Nadu	1	1
24.	Uttar Pradesh	22	17
25.	West Bengal	25	23
	Total	**287**	**246**

GRAND TOTAL (i)P.G. =456

(ii)M.E. = 359

Typically, the P.G. courses in Hydrology and related areas at Indian Institute of Technology, Kanpur include: (i) Hydrologic Analysis and Design, (ii) Planning, Design and Development of Water Resources Systems, (iii) Groundwater system Analysis, (iv) Water Resources Engineering, (v) Open Channel Hydraulics, (vi) Unsteady Flow, (vii) Coastal Engineering, (viii) Sub-surface Geophysical Exploration, (ix) Hydrogeology of India, (x) Resource Development Using Remotely Sensed Imagery, etc.(I.I.T., Kanpur, 1989).

UNDERGRADUATE EDUCATION IN HYDROLOGY

The science of hydrology in general has developed within many fields of study, viz. Civil Engineering, Meteorology, Geophysics, Geology, Physical Geography, Agricultural Engineering, etc. without developing a clear identity of its own. This is mainly due to uncertain career prospects for hydrology as a profession in the country. Generally at undergraduate level, hydrology and related areas are covered with varying levels of coverage/emphasis.

Rao (1975) had suggested suitable restructuring of existing undergraduate programme in Civil Engineering to include specialisation in hydrology and water resources in the form of electives, and minor and major projects in the prefinal and final your classes. Chandra and Seth (1975) had recommended a four year integrated programme of study for Bachelor of Engineering (Hydrology) degree. However, mainly due to absence of cadre of engineer hydrologists/water resources engineers in the central and state agencies, there is no formal programme for hydrological education so far in the country at under-graduate level.

EDUCATION & TRAINING OF OBSERVERS, TECHNICIANS AND JUNIOR HYDROLOGISTS

In order to meet the needs of short term and long term plans for water resources development in the country, creation of suitable mechanism for education and training of hydrologists is not only necessary at degree and post-graduate level but also at junior levels, viz. overseer, technician, observer, etc. Adequate trained manpower is necessary to improve the capabilities of operational organisations in the centre and in the states in regard to observation as well as primary and secondary processing of hydrological data. Though there is no regular course for technician training in hydrology, meteorology and other related fields, various organisations like Central Water Commission, India Meteorological Department, Central Ground Water Board, State Irrigation Departments, etc. dealing with subjects related to hydrologic cycle have created facilities for on the job and in-service training of personnel. There is, however, no formal training programme for technicians and observers. There is only partial coverage of hydrology as a subject under civil engineering diploma courses to provide some background to personnel at overseer/junior hydrologist level. No formal training at diploma level is available mainly due to absence of cadre. Currently, this vital area for training of personnel at junior levels has been receiving attention mainly due to emphasis being given under International Hydrological Programmes of UNESCO. Gilbrich (1991) has highlighted various activities of UNESCO in this direction including compilation of curricula and syllabii for technician training, lecture notes, guidance material for teachers and supervisors of hydrology technicians, etc. The

Water Resources Development Organisation of Karnataka State (W.R.D.O., 1992) has brought out publications for use and reference of the personnel dealing with hydrological analysis. These include: (i) Precipitation Manual, (ii) Manual on Stream Gauging, (iii) Manual on Design Flood Estimation, (iv) Manual on Estimation of Yield, (v) Manual on Flood Routing, (vi) Manual on Hydrometeorological Network. The sub-committee of High Level Technician Committee on Hydrology in 1986-87 had gone through various aspects of technician training and recommended a course structure for a two month training programme for technicians and 3 weeks programme for observers.

SHORT TERM COURSES AND TECHNOLOGY TRANSFER ACTIVITIES

The International Hydrological Programme of Unesco has laid stress on not only regular programmes at P.G. Diploma and Master's degree level, but also on short term courses and workshops for interaction, exchange of ideas and information and continuing education and training of professional field personnel as well as academic faculty. Significant developments have taken place in this area. Summer courses, refresher courses and continuing education programmes are being organised covering various aspects and new technologies in hydrology and water resources, not only by academic institutions like IIT's, University of Roorkee, Engineering Colleges but also by Central Water Commission, India Meteorological Department, Central Ground Water Board, National Institute of Hydrology, Central Water & Power Research Station, Centre for Water Resources Development and Management, National Remote Sensing Agency, Water & Land Management Institutes, Technical Teachers Training Institutes, Staff Training and Irrigation Research Institutes in States, etc. Karnataka Engineer Staff Training College at Krishnarajasagar, Engineering Staff College at Nashik and other similar State institutes have been organising short term courses for training of in-service personnel in various areas of hydrology, e.g. estimation of yield, design flood, flood routing, flood forecasting, use of computers in hydrological analysis, etc.

The National Institute of Hydrology was set up at Roorkee in December 1978 by Government of India as a nucleus for studies and research in hydrology in the country with the objective to undertake, aid, promote and coordinate activities in area of hydrology, has made a remarkable contribution in this area through organisation of short duration workshops at Roorkee and in different States for transfer of technology with emphasis on analysis, design and software. A large number of participants from Central and State Govt. Organisations as well as academic organisations have benefited from such training. Some of the important areas in which workshops have been organised include:

(i) Flood Estimation by Unit Hydrograph Technology;

(ii) Flood Frequency Analysis;

(iii) Ground Water Modelling Using Tyson Weber Model;

(iv) Observation, Processing and Analysis of Precipitation Data;

(v) Flood Routing & Flood Forecasting;

(vi) Design Storm & Design Flood;

(vii) Reservoir Operation;

(viii) Urban Hydrology;

(ix) Remote Sensing Applications in Hydrology;

(x) Agricultural Drainage;

(xi) Ground Water Balance;

(xii) Snow Hydrology;

(xiii) Water Quality Modelling;

(xiv) Application of SHE Model;

(xv) Himalayan Hydrology with emphasis on spring flow;

(xvi) Low flow modelling & forecasting;

(xvii) Project Hydrology.

POLICIES AND PROGRAMMES

The High Level Technical Committee on Hydrology in its 7th Meeting held in December 1985 considered and made detailed review of specific problems in hydrology. Various broad areas needing concerned efforts were identified including education and training. It was suggested that training activity of hydrologists at different levels should be improved, rationalised and suitably strengthened through necessary inputs at Central and State levels.

The long term science and technology programme for research in water resources development (CBIP, 1986) has listed the following areas under education and training:

(i) To suggest engineering programme with futuristic element as students entering today will be in profession during the next 45 years well beyond the beginning of the 21st century. During this period it is quite possible that even emerging technologies may become obsolete;

(ii) To examine necessity of different curricular at different levels of engineering education to create manpower for carrying out functions of production, operation and maintenance and those of research and development for new technology;

(iii) To identify highly specialized areas for post-graduate programme to meet the requirements of the national economy;

(iv) To examine the desirability of orientation of doctoral work in engineering towards design and technology research;

(v) To create a cell in CBIP to interact with Government Departments, Research Institutions, Industrial Groups to identify periodically emerging technologies and manpower requirements;

(vi) To recommend short term training courses and training workshops to update in service engineers in emerging technologies;

(vii) To suggest training programmes for skilled workers, technicians for introducing sophisticated instruments and measurement technique;

(viii) To suggest linkages amongst different levels for effective functioning of the system so as to promote smooth movement from lower level to higher positions of responsibilities in the working lines.

National Water Policy document released by Ministry of Water Resources, Government of India in Sept. 1987 lays due emphasis on training and recommends that a perspective plan for standardised training should be an integral part of water resource development and the training should extend to all the categories of personnel involved in these activities as also the farmers.

HYDROLOGY CELLS IN STATES

The creation of hydrology cells or units in various States have been a significant development towards consolidation of hydrology related activities as well as training activities. In Gujarat, hydrology cell functions under Central Designs Organisation under charge of a Superintending Engineer. In Andhra Pradesh, hydrology and statistics Division functions under Investigation Unit of Irrigation & CAD Department under the charge of a Deputy Director. In Rajasthan, hydrology unit of irrigation department is functioning under the change of a Deputy Director (Hydrology). In Maharashtra, hydrology division is working under Central Designs Organisation at Nashik. In Tamil Nadu, Institute of Hydraulics and Hydrology at Poondi has been functioning since 1973. In Madhya Pradesh, hydrology cell has started functioning since 1987 under Bureau of Designs for Hydel and Irrigation (BODHI) under the charge of a Director. In Karnataka, hydrology unit is headed by a Superintending Engineer under Water Resources Development Organisation. In Kerala, hydrology unit comes under Irrigation, Design and Research Board and is headed by Joint Director (Hydrology). In other States like Uttar Pradesh, Bihar, West Bengal, etc. also units have been functioning. The establishment of Centre for Water Resources Development & Management (CWRDM) in Kerala has not only led to significant developments in research and development activities in hydrology but also also contributed to training activities.

REMARKS

There has been significant progress since independence in hydrologic education and training. Noteworthy features include post-graduate level programmes and technology transfer programmes through short term courses. For informal (on the job) training of auxiliary personnel and good facilities have been created in various central agencies and State Departments dealing with water resources development and management. Recently, a number of States have created specific set up for hydrology related activities. There are 67 major river basins and a few hundred medium river basins in the country, which can be identified for intensive study and integrated development. The techniques will have to be developed for the collection of reliable and representative data of precipitation, evapotranspiration, infiltration, groundwater recharge, soil moisture, runoff, baseflow groundwater, floods and droughts in addition to other data relating to physiographic and climatic characteristics of river basins. This will involve setting up of good data collection network and facilities for

processing and analysis of data. In order to meet the requirements of long range plan for optimal use of water resources, a vast manpower resource will be needed with specialised knowledge and training in various aspects of hydrology. It has been estimated that about 5000 professional and research hydrologists and about 18000 sub-professionals will be needed in next 20 years or so. In order to meet the short term and long term requirement for water resources development in the country, it is necessary to create suitable mechanism for manpower development and creation of cadre of hydrologists at different levels, viz. observers, technicians, junior hydrologists, general hydrologists, specialist hydrologist, etc. in the States and Central Organisations. Recent developments in computers, electronic instrumentation and analysis techniques have led to significant developments in their application in hydrology. There is need for creation of facilities for formal training of observers, technicians, junior hydrologists and general hydrologists. There is need for introduction of suitable programmes in curricula and development of course material at ITI, Polytechnic (Diploma) and undergraduate levels on a selective basis, besides further strengthening and diversification of post-graduate diploma and Master's Degree programmes and instructors/teachers training. These steps are particularly necessary, since in near future, major problems due to effect of man's activities on hydrological regime and global environment, would require much more in depth studies and knowledge of many disciplines including sound scientific base on hydrology. As pointed out by Nash et al (1990), the present structure of hydrological education, generally tailored to the needs of problem solving engineering approaches, would need to be suitably restructured to provide it a sound scientific basis. The authors have rightly pointed out the following aims and content of education in hydrology at University level, which are equally relevant for providing necessary direction to hydrologic education and training activities in India:

(a) To develop and improve awareness of the totality of interconnected (mainly) physical processes involved in the hydrological cycle;

(b) To provide the maximum possible training in relevant areas of the basic scientific disciplines underpinning hydrology;

(c) To develop the connections between those basic disciplines and the scientific study of various hydrologic processes;

(d) To stress the central roles of observation and experimentation in the scientific study of hydrology;

(e) To develop more fully and clearly the connections between scientific knowledge of hydrological processes and the current (and potentially improved) professional practice of hydrology.

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