

WORLD METEOROLOGICAL ORGANIZATION

GUIDELINES FOR THE EDUCATION AND TRAINING OF PERSONNEL IN METEOROLOGY AND OPERATIONAL HYDROLOGY

VOLUME II: HYDROLOGY

Editors: G. Arduino, I. Drăghici, M.J. Hall,
F.M. Holly Jr., A. Van der Beken

Prepared under the guidance of the
Executive Council Panel of Experts on
Education and Training

FOURTH EDITION



WMO-No. 258

Secretariat of the World Meteorological Organization
Geneva – Switzerland



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relating to education and training

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WMO-No. 258

Secretariat of the World Meteorological Organization
Geneva – Switzerland
2003

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ISBN 92-63-14258-0

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FOREWORD

The present fourth edition of the *Guidelines for the Education and Training of Personnel in Meteorology and Operational Hydrology*, departs considerably from its predecessors, both in structure and content, as well as in the spirit of its utilization. In particular, for the first time this publication is released as two separate volumes: Volume I – *Meteorology* and Volume II – *Hydrology*.

In the Foreword to Volume I of this fourth edition of the *Guidelines for the Education and Training of Personnel in Meteorology and Operational Hydrology*, I stated that the “availability of adequately trained human resources in any institution is most critical to its success; and education and training play a significant role in this connection”. The Convention of the World Meteorological Organization (WMO) includes, as one of the purposes of WMO, the encouragement of training in meteorology and related fields and assistance in the coordination of international aspects of such training. Since its inception in 1950, WMO has been contributing significantly to the promotion of pertinent education and training activities.

Through its Education and Training Programme (ETRP), WMO has played a significant role in the development and strengthening of the National Meteorological and Hydrological Services (NMHSs), especially in the developing world. The promotion of capacity building and human resources development have been key areas under the ETRP. Recent WMO activities in education and training include re-defining its classification of meteorological and hydrological personnel, strengthening the role of WMO Regional Meteorological Training Centres, training of trainers, provision of technical support, organization of training events, implementation of the fellowship programme and the preparation of training publications, such as this publication. These activities are undertaken to respond to trends, developments and evolving needs brought about by changing socio-economic circumstances such as globalization and rapid technological advances, including information and communications technology.

In the Foreword to Volume I of this new edition, I noted that “now at the beginning of the 21st century, formidable additional challenges and opportunities are already on the horizon”, and stressed that “meeting those new challenges and availing of emerging opportunities will require better educated and skilled meteorological and hydrological personnel”.

It is fitting to note that this publication was finalized in 2003, the International Year for Freshwater. The aim of the year is to raise awareness of the importance of protecting and managing freshwater. The adequate education and training of personnel working in the fields of hydrology and water resources is an essential component of the sustainable management of our valuable water resources.

The former edition of this publication, which contained the traditional WMO classification of meteorological and hydrological personnel as well as the curricula for their education and training, has been substantially revised. This present edition aims at providing reference guidelines, which should be:

- Applicable in an international context, in particular in planning international training events and in assessing candidates for those events, including those funded under the WMO Programme; and
- Adaptable to a national context, in particular in National Meteorological and Hydrological Services from developing countries.

While structural consistency between Volume I and Volume II was an important objective, due consideration had to be given to the fact that the presumed audience of the Volumes would be different:

- On the meteorological side, the potential readers of Volume I are likely to be from a relatively small and quasi-homogenous *meteorological community* gathered particularly around the National Meteorological Services — usually a well defined public institution in place in every country.
- On the hydrological side, given the very broad scope of Integrated Water Resources Management (IWRM), Volume II should be addressed not only to the *hydrological community* but also to the fairly large and heterogeneous *water community*, spread through many public and private institutions with varied (sometimes conflicting) interests.

In order to accommodate this major challenge of a likely varied audience, this volume keeps a broad vision and does not pretend to cover everything at the same level of detail. In particular, the curricula recommended for qualification of hydrological personnel is focused on the acquisition of knowledge and a core set of skills that would support a reasonable subset of IWRM activities, which, for convenience, were grouped into four generic branches of activity: hydrology and water resources; complemented by data systems management, environmental management and socio-economics and law.

I wish to take this opportunity to convey the gratitude of the Organization to the members of the Executive Council Panel of Experts on Education and Training for guiding the preparation of this publication. I would also like to thank the WMO Commission for Hydrology and the UNESCO Division of Water Sciences for guidance and review. Finally, I would like to thank the members of the Editorial Task Force for preparing this volume and the two external reviewers for their contribution.

Water is the most important resource on Earth. It is also a finite resource and there is clear and convincing evidence that the current patterns of water use cannot be sustained in many regions of the world. Increasing pressure on finite supplies of freshwater and degradation of these supplies are weakening one of the essential resource bases on which human society is built, and human lives and investment are at increasing risk from droughts and floods. The availability of adequately trained hydrologists to assist Governments in the sustainable development and management of their vital water resources is a key prerequisite to addressing these issues. I believe that this publication will be of particular assistance to the hydrological community in this regard.

(G.O.P. Obasi)
Secretary-General
World Meteorological Organization

PREFACE

Guidelines for the education and training of scientific and technical personnel have always been one of the top priorities of the World Meteorological Organization. WMO published the first edition of the *Guidelines for the Education and Training of Meteorological Personnel* in 1969. Later, taking into account the amendment to the WMO Convention in 1975 on the inclusion of responsibilities for operational hydrology within the sphere of the WMO activity, two further editions were issued in 1977 and 1984 under the present title (*Guidelines for the Education and Training of Personnel in Meteorology and Operational Hydrology*).

In 1996, the Executive Council Panel of Experts on Education and Training developed basic proposals on the preparation of a new, fourth edition of the *Guidelines*. Moreover, the Panel noted that the effects of globalization on the activities of National Meteorological and Hydrological Services (NMHSs), increasing natural disaster-related problems and growing interdisciplinarity in the studies of climate, environment and water resources would require more broadly and expertly educated personnel with greater flexibility to work within different fields of NMHSs responsibilities. The necessity of more focused professional training oriented to the NMHS users within all major applications of meteorological and hydrological provision was emphasized.

As a result, early in 1998, the Panel endorsed a proposal on a transition to a simplified two-level classification system common for meteorology and operational hydrology and on the preparation of two separate volumes of the *Guidelines* — one on meteorology (Volume I) and one on hydrology (Volume II). The Panel established an Editorial Task Force (ETF) to prepare detailed curricula and oversee the preparation of each volume.

The volumes were compiled by small teams of specialists agreed by the Panel. To prepare and review Volume II, the Panel invited specialists from WMO and well known organizations involved in water management and best educators in the field. As a result, the ETF for the volume on hydrology consisted of the following specialists:

Professor G. Arduino, from the WMO Department of Hydrology and Water Resources, overall coordinator of the texts contributed by the ETF members and other experts;

Dr I. Drăghici, from the WMO Department for Education and Training, liaison editor between the two volumes, charged with ensuring the overall coherence of the fourth edition;

Professor M. J. Hall, from the UNESCO-IHE Institute for Water Education (formerly the International Institute for Infrastructural, Hydraulic and Environmental Engineering – IHE), Delft, the Netherlands, UNESCO representative;

Professor F. M. Holly, Jr., from IIHR Hydrosience and Engineering, University of Iowa (USA), and President of IAHR (International Association for Hydraulic Engineering and Research), Chairman of the ETF;

Professor A. Van der Beken, from the Department of Hydrology and Hydraulic Engineering, Vrije Universiteit Brussel (VUB), Brussels (Belgium), Panel representative and Vice-Chairman of the ETF.

On behalf of the Executive Council Panel of Experts I would like to express my sincere gratitude to all members of the Editorial Task Force for their difficult and fruitful work.

During the preparation of the *Guidelines* the comments and recommendations of specialists from the WMO Commission for Hydrology and from the UNESCO Division of Water Sciences were very useful. Valuable proposals on improvements to the text have been made by two external reviewers: Professor K. P. Georgakakos (USA) and Mr G. Van Langehove (Namibia).

Repeating the structure of Volume I, Volume II consists of two parts (A and B) and some appendices. Part A includes chapters 1 to 5 where general guidelines are described and Part B consists of chapters 6 and 7 with case studies.

Chapter 1 describes the terms of reference of the WMO Commission for Hydrology and basic features of the new classification system for meteorological and hydrological personnel approved by the WMO Executive Council at its fiftieth session (1998) and by Thirteenth Congress (1999). Chapter 1 also describes the history of hydrology and the evolution of water resources management, the present state of hydrology and offers some perspective for the future.

Chapter 2 presents the major hydrological qualifications within the wider sphere of jobs in Integrated Water Resources Management (IWRM). In addition to Hydrologists and Hydrological Technicians there are many other professions related to water resources. These professions are practised in the following branches of IWRM: Hydrology and Water Resources (HWR), Data Systems Management (DSM), Environmental Management (ENM), and Socio-economics and Law (SEL). The main responsibilities and the most typical instructions for personnel engaged in these branches are described.

Chapters 3 and 4 present the Basic Instruction Packages (BIP) for graduate Hydrologists and Hydrological Technicians. The BIP-HWR, considered essential in the preparation of any hydrologist, is described in greater detail compared with other branches of the IWRM recommended for the hydrological training of complementary professions. Regarding the training of Hydrological Technicians, two career paths are presented: Instrumentation and Measurement Technology (IMT) and Information and Communications Technology (ICT).

Chapter 5 describes the need for continuing professional development and training of personnel. Basic concepts, methods, techniques and strategies for continuing education and training (CET) are given; relationships between different IWRM jobs are considered and CET and human resources policy are briefly presented.

Chapter 6 contains BIP case studies for Hydrologists and Hydrological Technicians. Here the contribution of Environment Canada in the training of Hydrological Technicians should be noted.

Chapter 7 contains examples of the requirements of different jobs within the framework of IWRM. These examples have been kindly provided by the following experts: P. Chola (Zambia), C. Farias (Venezuela), D. Rabuffetti and S. Barbero (Italy), I. Shiklomanov (Russian Federation) and B. Stewart (Australia).

Appendix 1 contains information on quality assurance systems in higher education and provides an example of real criteria for the accreditation of engineering programmes. Appendix 2 contains an example job description — regional manager. Appendix 3 is a glossary of terms and Appendix 4 contains a list of references and annotated bibliography.

At the end of the Volume a list of references and annotated bibliography is given.

In conclusion, I would like to express my sincere gratitude to all present and past members of the Executive Council Panel of Experts on Education and Training,

whose great experience and knowledge of different aspects of hydrological and meteorological education and training made it possible for WMO to realize the time consuming and complex work involved in preparing the fourth edition of the *Guidelines*.

My most profound gratitude is to Dr J .W. Zillman who was the Chairman of the Executive Council Panel of Experts on Education and Training for many years and who contributed much to the good organization and successful outcome of the work in preparing this volume.

(Dr A. I. Bedritsky)
Chairman of the Executive Council Panel
of Experts on Education and Training

PART A

BACKGROUND AND GUIDELINES

Background and guidelines

Domain of hydrology and hydrologists

Main branches of activity in hydrology and water resources

Basic Instruction Packages for Hydrologists (BIP-HWR) and complementary professionals (BIP-DSM, BIP-ENV, BIP-SEL)

Basic Instruction Packages for Hydrological Technicians (BIP-HTIMT, BIP-HTITC)

Continuing Education and Training (CET)

“I call therefore a complete and generous education that which fits a man to perform justly, skilfully and magnanimously all the offices both private and public...”

(John Milton, On Education; 1644)

Part A comprises five chapters providing generic guidance on the requirements for the initial qualification and early specialization of hydrological personnel – graduate Hydrologists and Hydrological Technicians who would support a reasonable sub-set of activities in Integrated Water Resources Management (IWRM).

Chapter 1 recalls the terms of reference of the WMO Commission for Hydrology and the essential features of the new system for classification of meteorological and hydrological personnel, approved by the WMO Executive Council at its 50th session (1998) and endorsed by the WMO Congress at its 13th session (1999). It also elaborates on the past evolution of hydrology and water resources and on current practice and future perspectives in hydrology.

Chapter 2 introduces the basic qualifications involved in hydrology within the broader context of IWRM activities, which, for convenience, were grouped into four generic branches of activity:

Hydrology and Water Resources (HWR);
Data Systems Management (DSM);
Environmental Management (ENV);
Socio-economics and Law (SEL).

Reflecting these branches of activity, it is recognized that in addition to hydrological personnel, there are also many Complementary Professionals working in the field of water resources. Principal responsibilities and typical instruction subjects required for qualifying these personnel are highlighted.

Chapters 3 and 4 describe the Basic Instruction Packages (BIP) for university-level graduate Hydrologists and for non-graduate Hydrological Technicians respectively. The BIP-HWR, considered as essential for the preparation of any Hydrologist, is described in more detail than the BIP-DSM, BIP-ENV, or BIP-SEL,

which are recommended for the hydrological preparation of Complementary Professionals. Concerning the preparation of Hydrological Technicians, two career stems are considered, namely – Instrumentation and Measurement Technology (IMT) and Information and Communications Technology (ICT).

Chapter 5 goes beyond the initial qualification of hydrological personnel, highlighting the need for continuing professional development of those personnel. The main concepts, strategies, methods and supporting techniques for continuing education and training (CET) are presented; and the relationship between IWRM-jobs and CET is briefly addressed.

CHAPTER 1

DOMAIN OF HYDROLOGY AND HYDROLOGISTS

Background

Evolution of hydrology and water resources

Current practice and future perspectives in hydrology

At its 13th session, held in Geneva in 1999, the WMO Congress adopted a new system for the classification of personnel in meteorology and hydrology. Although by now generally regarded as a component of earth systems science, involving the scientific study of processes within the hydrological cycle, hydrology has also been an important tool for the solution of pressing practical problems. This dichotomy has been compounded by the increasing emphasis in the last two decades of the 20th century on the management of water resources, formally articulated in the so-called Dublin Principles of 1992. Taken together with the growing importance of Information and Communications Technology (ICT), these changes have led to an influx of professionals from ICT and life and social sciences into Hydrology and Water Resources (HWR). The processes of globalization and commercialization have also contributed to fundamental changes in the career paths of water sector professionals away from the traditional public service-orientated models of the 1970s and 1980s. This diversification in the scope and career opportunities in HWR provides particular challenges in defining guidelines for education and training of hydrological personnel.

1.1 **BACKGROUND** The present guidelines respond to the need, articulated by the Commission for Hydrology, to update the syllabi and provide examples of competency requirements for hydrological personnel (see new classification of personnel in meteorology and hydrology, WMO Report 258, Volume I.)

Commission for Hydrology The activities and scope of the Commission for Hydrology have been defined in the 1999 edition of WMO-No. 15, *Basic Documents*. The Commission shall be responsible for:

- (a) Advisory activity in hydrology and water resources, including, but not limited to:
 - (i) The measurement of basic variables characterizing the quantity and quality of water and sediment in the hydrological cycle;
 - (ii) The acquisition of other related characteristics describing the properties of basins, rivers, and the inland water bodies;
 - (iii) The collection, transmission, processing, storage, quality control – archiving, retrieval and dissemination of data and information;
 - (iv) Hydrological forecasts and warnings, both under natural and accidental conditions;
 - (v) The development and improvement of methods and technology required for the items above;
 - (vi) The application of water-related data and information to the assessment, effective management, and sustainable development of water resources and to the protection of society from hydrological hazards;
- (b) Promoting and facilitating the international exchange of experience, transfer of technology, research uptake, education, and training and development to meet the needs of National Hydrological Services or other organizations fulfilling the functions of such Services including programme management and public awareness (e.g. through the Hydrological Operational Multipurpose System and other mechanisms);
- (c) Promoting and facilitating the international exchange and dissemination of information, terminology, data, standards, forecasts and warnings;
- (d) Promoting the collaboration and linkages among operational hydrology, meteorology, and environmental management;
- (e) Raising awareness in the wider community of the social, economic and environmental significance of water and promoting the role of hydrology in the mitigation of hydrological hazards and in the development and management of water;
- (f) Supporting cooperation between WMO, the International Hydrological Programme of the United Nations Educational, Scientific and Cultural Organization, the International Association of Hydrological Sciences and other governmental and on-governmental organizations on matters related to hydrology and water resources;
- (g) Supporting and, where appropriate, taking the lead in, coordinating within WMO terrestrial water-related matters, including the activities of the regional associations' Working Group on Hydrology.

These responsibilities in general, and activities (a)(iv) and (b) in particular, imply the need for well-trained personnel.

Classification of personnel A new classification scheme for personnel in meteorology and hydrology was approved by the WMO Executive Council at its 15th session (Geneva, 1998) and endorsed by the WMO Congress at its 13th session (Geneva, 1999). The new classification system identifies two main categories of personnel – graduate

professionals and technicians – and within each category there are three career development levels: junior-, mid- and senior-level. The junior-level qualification (i.e. job entry level) of personnel assumes the successful completion of a Basic Instruction Package (BIP), specifically designed for graduate Hydrologists (H) and respectively for Hydrological Technicians (HT). Both Hydrologists and Hydrological Technicians should progress to higher grades in line with nationally determined career stages, for instance, according to national civil service career schemes. A Hydrological Technician could be re-categorized as a Hydrologist, after obtaining a university degree and after completing a suitable BIP programme.

The new WMO categorization of personnel became effective on 1 January 2001. The actual implementation is expected to be gradual, in recognition that some national meteorological and hydrological services may require a transition period of a few years, but should be completed before 2005.

1.2 EVOLUTION OF HYDROLOGY AND WATER RESOURCES

“Hydrology is the science that deals with the waters above and below the land surfaces of the Earth, their occurrence, circulation and distribution, both in time and space, their biological, chemical and physical properties, their reaction with their environment, including their relation to living beings.” (UNESCO/WMO 1992.)

The origins of hydrology as a geophysical science are often associated with a publication by a former lawyer, Pierre Perrault (1608–1680), whose study of the River Seine provided experimental proof that rainfall over the catchment of a river is sufficient to sustain streamflow. A later contribution by an English Astronomer Royal, Edmund Halley (1656–1742), showed that evaporation from the oceans was enough to replenish the rivers that flowed into them, thereby placing the existence of the hydrological cycle beyond reasonable doubt. In a review published in the late 1960s, Linsley (1967) proposed that the development of hydrology subsequent to Perrault’s experiments could be conveniently divided into three distinct epochs: the era of empiricism, the era of correlation and the computer era.

The era of empiricism was notable for the almost complete absence of concurrent measurements of precipitation and streamflow. In order to estimate flood flows, heavy reliance was placed on empirical formulae and envelope curves. The well-known Rational Method, developed in Ireland by Mulvaney (1852), dates from these times, and is still in limited use today as a means of designing the drainage systems of small urban developments. The use of flat-rate rainfall intensities, independent of rainfall duration, is another contemporary technique, which was employed in the design of London’s system of interceptor sewers by Sir Joseph Bazalgette (1819–1891).

The era of correlation from 1930–1955 was marked by substantial progress, with work taking advantage of the data then becoming available from systematic programmes of measuring both precipitation and streamflow. Statistical methods for flood frequency analysis were increasingly employed, and influential contributions, such as that of Sherman (1932) on the unit hydrograph technique, were produced, mostly in contemporary engineering journals.

The increasing availability of digital computers post-1955 led to an almost explosive growth in the modelling of the relationship between precipitation and river flows, the early phases of which borrowed heavily from the mathematics of systems analysis, as developed originally in electrical engineering. The utility of operations research techniques also began to be explored in water resources planning and management. In addition, statistical methods were applied to the prediction of hydrological extremes and the regionalization of hydrological variables, and time-series analysis was employed to study the stochastic structure of instrumental records. Simultaneously, the overall power of digital computers was

increasing in inverse relationship to their cost, rendering feasible the solution of larger and larger sets of equations, feeding on more and more data.

The Intel Corporation developed the first microprocessor in 1971 and in 1981 IBM launched the first personal computer. With the more recent development of parallel processors and networking, the computer era can in many ways be said to have continued right up to the present day. However, in retrospect, research interests and engineering applications can be seen to have undergone some subtle changes, largely dating from the activities during the International Hydrological Decade (IHD) from 1965–1974. The IHD was notable for renewed emphasis on field measurement and attempts to understand and model the processes within the hydrological cycle more fully. The emphasis on process studies has also been partly stimulated by the realization that the pressures of population growth are having increasing impacts on hydrological processes, particularly through changes in land use, such as urbanization and deforestation. Conversely, society at large is increasingly suffering from the impacts of hydrological extremes in the form of floods and droughts. During the 25 years from 1966, the number of people affected by floods exceeded that associated with all other major disasters combined (Fattorelli *et al.*, 1999).

These events have served to reinforce the apparent schizophrenia in hydrology. On the one hand, hydrology is a geophysical science, involving the scientific study of processes within the hydrological cycle, and on the other it is a tool for the solution of pressing practical problems. To a large extent, hydrologists share this condition with hydraulic engineers, whose educational background is based upon both sciences (e.g. fluid mechanics and geosciences) and applied topics (e.g. hydraulic structures and engineering hydrology – see Kobus *et al.*, 1994). The result within the hydrological community has been a continuing debate over the desirability, if not the necessity, for an increased emphasis on basic sciences in hydrological education as proposed by Nash *et al.* (1990) and National Research Council, USA (1991). Indeed, Nash (1992) went so far as to refer to the “failure” of practising hydrologists to maintain scientific discipline and to indulge a fascination with tools of analysis rather than to concentrate on their application.

The problems are compounded by the discernible change in attitude that has occurred within water resources planning and management during the last two decades that could be interpreted as inaugurating another notable era. For want of a better title, this new phase of activity could be reasonably well described as the management era.

A clear illustration of the change in attitude referred to above may be found in one of the Guiding Principles emanating from the International Conference on Water and the Environment that was held in Dublin in January, 1992. According to this principle, water has an economic value in all its competing uses and should be recognized as an economic good. Managing water as an economic good is seen as an important means of achieving efficient and equitable use and of encouraging conservation and the protection of water resources. As the World Bank (1993) have observed, water supplies are invariably priced below their economic value, thereby providing little incentive to adopt conservation measures. Formerly, water sector institutions operated with a largely supply-orientated approach, i.e. making the right amount of water available for a particular use at the right time and in the right quantity. This traditional attitude is now evolving into a more demand-orientated approach, the purpose of which is to ensure sustainability of the water environment for multiple uses as a means/tool of economic development.

This change of emphasis has also taken place against the background of even further advances in information and communications technology (ICT). These have revolutionized almost all aspects of water resources management, from asset

inventories and billing systems, to hydrometric data collection and archiving. In addition, major changes have taken place in institutional arrangements in the water sector. Basin-wide authorities are considered as valuable institutions for water resources management and are likely to become even more valuable and numerous in the future. However, large, basin-wide authorities are often regarded as operating a natural monopoly, which frequently results in unreliable and inadequate services to consumers and insufficient attention to maintenance and renewal of assets. Remedies have been sought by way of institutional reforms involving public-private partnerships, public limited companies or stock corporations and even full divestiture to the private sector. A particular consequence of full divestiture, where the shares of the company are quoted on the local stock market, has been the out-sourcing of services that were formerly supported in-house. Technical services in general and engineering design and maintenance in particular tend to be provided on a consultancy contract basis. The net result has been a marked influx of professionals into hydrology and water resources from increasingly diverse and often non-technical backgrounds. Such changes pose new challenges in training and professional development, such that the traditional technology-based career preparation for hydrologists and water resources professionals must be supplemented by complementary instruction packages for those with ICT, life science and social science backgrounds. This is the approach that has been adopted for the definition of Basic Instruction Packages that are outlined in Chapter 3.

For a more complete coverage of the issues in water related education, training and technology transfer, the reader is referred to theme 2.23 of the UNESCO-led Encyclopedia of Life Support Systems (EOLSS) (<http://www.eolss.net>).

1.3 CURRENT PRACTICE AND FUTURE PERSPECTIVES IN HYDROLOGY

As noted in Section 1.1, prominent among the advisory activities for which the WMO Commission for Hydrology is responsible are the measurement of basic hydrological variables; their processing, storage and retrieval; and the preparation and dissemination of forecasts and warnings of hydrological extremes. Traditionally, these functions have fallen within the remit of a National Hydrological Service, which is sometimes, but not always, linked administratively to the National Meteorological Service. However, the 1990s have seen gradual changes in this structure, partly through greater emphasis being placed on cost recovery, i.e. the perspective that the users of data should contribute substantially to the costs of their collection, and the concomitant reduction in budgets from central government sources. These changes are particularly apparent in countries, which have embraced the policy of privatization of water services. The net result has been a reduction in the size of hydrometric networks over a period which has seen increasing impacts on the hydrological cycle from anthropogenic activities, whose quantification depends heavily on the availability of lengthy, consistent and homogeneous hydrological records. Unfortunately, in some countries, hydrometry has been disrupted by civil unrest, which, even when conditions return to normal, can result in broken, and often inconsistent, records. In addition, in some countries, vandalism of hydrometric stations has made it difficult to obtain data from some important locations.

Simultaneously, the 1990s have seen a steady growth in the realization that the allocation of water resources, whose quantification depends entirely upon the efficacy of the hydrometric network, should be a process involving all stakeholders. Such stakeholders include, for example, direct stakeholders, experts from government, NGOs, private organizations and other affected parties often represented by environmental groups. Communication with these stakeholders will become an increasingly important skill for hydrologists.

Water allocation is ideally carried out at the river basin scale. The structure and remits of such a river basin authority are often far removed from that of the traditional hydrological service, particularly when the river basin concerned is

international in character. The result has been a growth in the number of specialists in water resources planning and management, whose training emphasizes more the socio-economic, legal and political aspects of water than hydrological processes and their measurement.

A further influence that has also manifested itself during the 1990s is globalization, which is well exemplified by the phenomenon of European companies running the water services of cities in South America or the Far East on a concessionary basis. Such arrangements provide an entirely new environment for professional activities, particularly in hydrology and water resources, and serve to illustrate the degree to which the career paths of water sector professionals have altered from the well-established public service-orientated models of the 1970s and 1980s. In brief, both the scope and the career opportunities for hydrological professionals have diversified considerably during the last decade, yet the requirement remains to define the Basic Instructional Packages and the job competencies of hydrological professionals.

CHAPTER 2

MAIN BRANCHES OF ACTIVITY IN HYDROLOGY AND WATER RESOURCES

Qualifications of hydrological personnel

Main branches of activities in Integrated Water Resources Management

Typical contents of main branches of activity

In order to fill a specific post, a person must possess the qualifications (knowledge and skill) as well as the competency to make decisions within an ethical framework. Modern society is particularly complex and the need to incorporate economic and legal considerations as well as scientific and technological concerns has given rise to the concept of Integrated Water Resources Management (IWRM). Within this framework, in addition to professionals in hydrology and water resources, the hydrologist may be seen to work with complementary professionals in three other branches of activity: data systems management; environmental management; and socio-economics and law. Similarly, two branches of activity (instrument and measurement technology and information and communications technology) are recognized for Hydrological Technicians. The definition of these grades of personnel must therefore be broadened to reflect the training requirements of complementary professionals. The latter can be conveniently grouped into the four branches mentioned above: hydrology and water resources, data system management, environmental management and socio-economics and law.

2.1 QUALIFICATIONS OF HYDROLOGICAL PERSONNEL

In general, a person is qualified to take up a job if he/she has the required knowledge and skills to perform specified tasks belonging to that job. In many cases, the job can be categorized as related to a given profession. The qualification is then associated with the profession. For example, a civil engineer is a person qualified to take up a job, which is categorized as belonging to the profession of civil engineer. However, society nowadays is so complex that it is becoming increasingly difficult to educate and train people to qualify for several types of jobs in a given profession. Thus, qualification may not apply to all jobs in a given profession. This is the case for hydrological professionals, as will be shown below, and several branches of activity and related responsibilities will be defined. In seeking to fill a particular post, care should be taken to distinguish among:

- Knowledge and skills as outcomes of education and training;
- Competency for a given job, which not only relates to knowledge and skill but also to aptitude, attitude, behaviour and perception. Besides this individual competency, team and organizational competency is also of utmost importance in dealing with changing environmental conditions;
- Ethical aspects of qualification and competency. These will generally increase in importance with career progression. Ethics deals with a moral framework for making good and right decisions.

These generalities have a particular interpretation in relation to hydrological personnel. With reference to the definition of hydrology given in section 1.2, hydrology is the direct link between meteorology on the one hand and oceanography and fluviology on the other hand. It includes both quantity and quality of water within the hydrological cycle as well as in the context of water management.

The concept of Integrated Water Resources Management (IWRM) reflects the complexity of modern society, and involves scientific, technological, economic, legal and administrative activities, aiming at:

- Assessment of water resources and the requirements of society;
- Determination of a technical and economic balance between resources and needs;
- Effective conservation or protection and sustainable development of water resources;
- Coordination within an institutional framework.

Personnel employed in hydrology and IWRM will necessarily be of different backgrounds because the activities undertaken cover a broad range of sciences and disciplines. For example, during the late 1970s, Van Dam (1979) envisaged that the main branches of activity encompassed flood protection, mitigation and management; water supply for agriculture, domestic and industrial purposes; management of water quality, including salinization and pollution of all kinds; hydropower production; development of inland navigation; recreational use of water; nature conservation; and environmental management. To many specialists, this list would equally be considered to describe activities in both hydraulics (i.e. the movement and conveyance of water on or below the earth's surface) and hydrology. However, writing some 20 years later, Wessel (1999, pp. 33–34) noted that IWRM would also need new professionals educated and trained in:

- Ethics and environmental ethics;
- Ecosystems-oriented management;
- Decision oriented systems approach, using policy analysis and risk analysis;
- Hydroinformatics; and
- Social economic systems oriented management.

<i>Window</i>	<i>Approach</i>	<i>Pertinent activities</i>
1	Natural abiotic science	Physics, chemistry, geochemistry, limnology, morphology, pedology, soil science, hydrology, hydro-meteorology, nuclear science, metallurgy, geology, geophysics, geodesy, mining engineering
2	Ecological biotic science	Ecology, biology, eco-hydrology, zoology, entomology, forestry, agriculture
3	Health science (pollution)	Toxicology, medicine, nutrition
4	Constructive engineering	Civil engineering, hydraulic engineering, fluid mechanics
5	Defensive engineering (precautionary principle, risk and hazards assessment)	Environmental and sanitary engineering
6	Habitat related	Cartography, geography, geodesic science, remote sensing
7	Institutional (legal system, decision making procedures and rules)	Law, decision theory
8	Policy (politics, policy documents, some laws)	Political science, policy science, planning theory, physical planning, (water) law
9	Ethical and cultural	Ethics, anthropology, aesthetics, philosophy, theology
10	History and trend oriented	History, linguistics
11	Social assessment (social stratification, policy analysis)	Sociology, ethnology, cultural anthropology
12	Social engineering (public participation, simulation, change agents, acceptability of measures, compliance with new rules)	Social psychology, psychology, process management
13	Management and operations (real-time control)	Systems engineering, operations research, management sciences, real-time control, crisis management
14	Financial	Public finance, statistics, economics, econometrics, environmental economics, hydro-economics
15	Mathematical	Mathematics, algebra, analytic geometry, calculus
16	Hydroinformatics	Mathematical modelling, GIS

Table 2.1—“Windows” on water problems as viewed by different water-related disciplines (adapted from Wessel, 1999. pp. 35–36)

Wessel (1999, pp. 35–36) subdivided water-related disciplines into 16 “windows” which offer different views of, or approaches to water problems (see Table 2.1). These analyses and others show clearly that organizations with responsibilities in hydrology and IWRM should employ people with qualifications spanning these different approaches. They will form the multidisciplinary teams for solving water problems.

2.2 MAIN BRANCHES OF ACTIVITY IN INTEGRATED WATER RESOURCES MANAGEMENT

The above observations are intended to be illustrative of the growing awareness of the holistic nature of IWRM and the need to broaden the vision of career paths to accommodate complementary professional activities. However, for the present purposes of defining guidelines in education and training, four main branches of activity are identified: hydrology and water resources, data systems management, environmental management and socio-economics and law.

Activities evolve through the techniques of observation, description and measurement, careful analysis and explanation, often using stochastic approaches towards modelling, simulation, synthesis, evaluation and decision making. Thus, water resources is clearly a multidisciplinary field and it is unlikely – rather impossible – that a Hydrologist could be educated and trained in all branches of activities in IWRM. The Hydrologist will work together with complementary professionals in water resources and the four categories of hydrological personnel introduced above will form the basis for the guidelines presented herein, as depicted schematically in Figure 2.1.

A matrix of main branches of activities versus responsibilities can be formed in order to find an appropriate set of topical units for education and training. Individual Basic Instructional Packages (BIPs), are discussed in detail in Chapters 3 and 4. Table 2.1

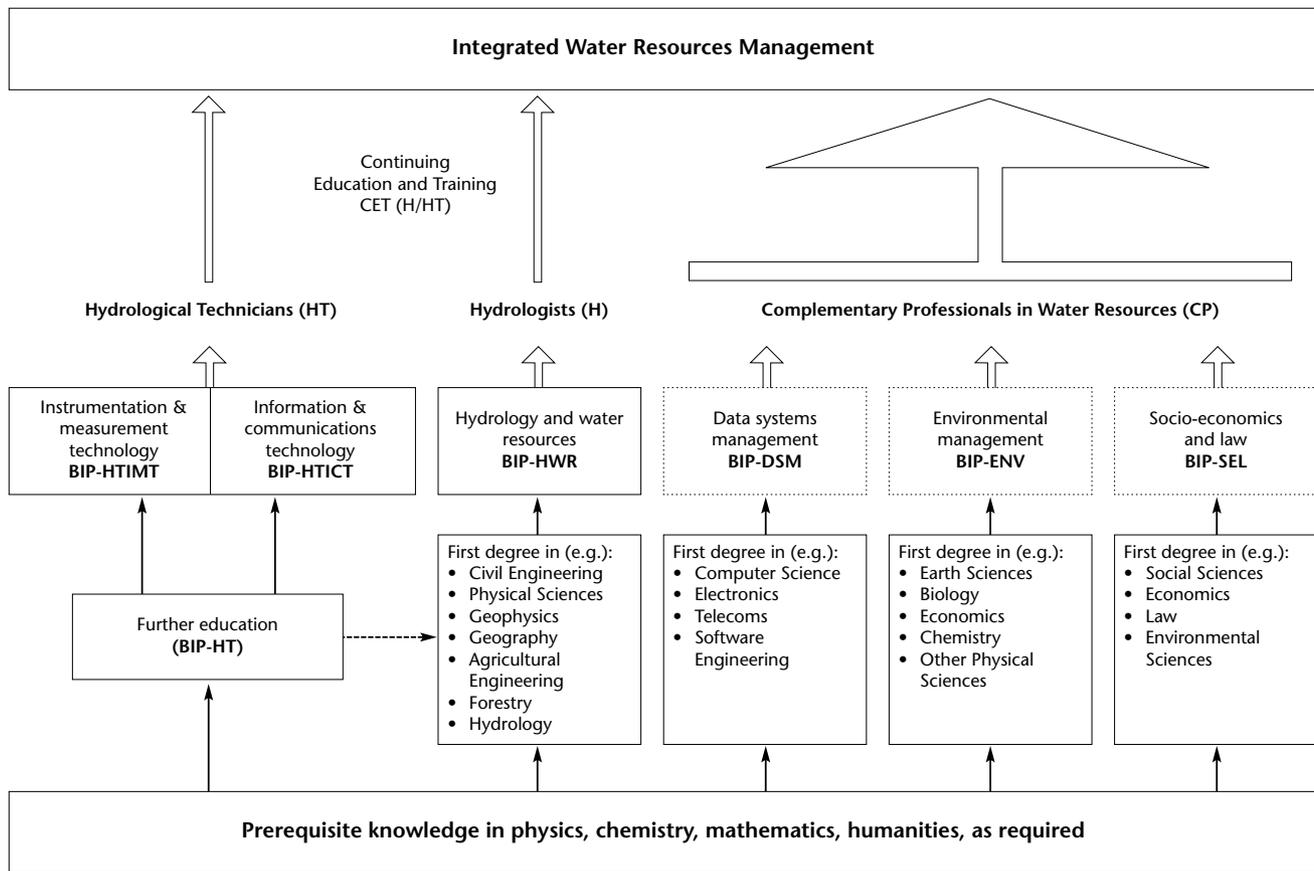


Figure 2.1—Hydrological personnel – career paths in the context of Integrated Water Resources Management

illustrates such a matrix and includes typical elements of the project cycle, e.g. planning, technical, economic and legal regulations and environmental impact assessment; design, implementation and construction; operation and maintenance; and general management including monitoring, forecasting, now-casting, hind-casting and risk analysis of natural and man-made hazards and disasters.

For Hydrological Technicians two main branches of activities, again depicted in Figure 2.1, should be considered: instrumentation and measurement technology, and information and communications technology. The first branch is the classical one related to the typical monitoring activities of surface and groundwater water quantity and quality, including measurements, operation and maintenance of the instruments, acquisition of characteristics for describing water systems, data processing and exploration of all kinds of information in a rapidly evolving environment. The second branch of activities applies information and communications technologies in the broad field of IWRM. These activities involve, therefore, technical and routine issues of image processing, development, operation and maintenance of large databases, GIS-applications, Internet applications (webmaster tasks, Internet searches, etc.).

The above discussion is sufficient to show that, even when only two grades of personnel – Hydrologists (H) and Hydrological Technicians (HT) – are recognized, their definition must be suitably broadened to meet the education and training needs of IWRM. This broadening specifically reflects the education and training requirements of the complementary professionals in water resources referred to above, and is presented in the flowchart of Figure 2.1. This figure identifies two BIPs for Hydrological Technicians and four for Hydrologists, and summarizes the structure, which is elaborated further in subsequent chapters.

2.3 TYPICAL CONTENTS OF MAIN BRANCHES OF ACTIVITY

The advancement of science and technological developments are catalysts for specialization in education and training. However, this specialization should be tempered by experience because problem solving activities should follow a holistic path unconstrained by the narrow view of a given specialization. In particular,

quantity and quality issues are commonly addressed in both HWR and ENV programmes.

The content of the main branches of activities, as described in Section 2.1, will depend largely upon the jobs and professions of the individuals. Of course, each of these combinations (group of responsibilities/subjects) needs specific tools or techniques, which appear in the BIPs, as described in Chapters 3 and 4. A job-oriented approach is introduced at a later stage (Chapter 7). The activities in a given career path are described below.

Hydrology and water resources engineering

Personnel employed in IWRM activities will necessarily be of different backgrounds in civil engineering, agricultural engineering, physical sciences, geophysics, geography, forestry, etc. They may receive further education and training, which further supports preparation for the profession of Hydrologist, with typical responsibilities in the field of hydrology and water resources. These responsibilities may be grouped into three categories, as outlined in Table 2.2.

It should be understood that this grouping does not mean that these responsibilities are independent. Monitoring and forecasting influence planning, design, operation and maintenance and are essential for crisis management, design and construction, as well as operation and maintenance, influence management. Table 2.1 lists the areas of responsibility within the specialization of hydrology and water resources. The list of subjects is given as a guide but cannot be considered to be exhaustive.

Data systems management

Personnel employed in IWRM in relation to data systems management are likely to have a background in computer sciences, software engineering or even electrical and electronic engineering. Further education and training may equip them to undertake professional responsibilities in Information and Communications Technologies (ICT). Table 2.1 lists typical subjects that fall within the DSM specialization, the scope of which is further defined in the relevant BIPs.

Table 2.2—Main branches of activity and operational responsibilities in Integrated Water Resources Management

<i>Branches of activity and responsibilities</i>	<i>Instruction subjects(*)</i>
Hydrology and water resources	
A. Monitoring and forecasting	A. Precipitation, evaporation, evapotranspiration, infiltration, runoff, water levels, flow rates, sediment transport, sedimentation, groundwater exploration and monitoring, water quality
B. Planning, design, implementation, construction, operation and maintenance	B. Drainage, irrigation, rainwater harvesting, groundwater abstraction, flood control, urban drainage, dams, reservoirs, lakes, hydraulic structures, fluvial hydraulics, navigation, water supply, waste water collection, water treatment and waste water treatment plants
C. Management, including crisis management	C. River basin management, early warning, disaster reduction, land use, soil conservation, recreation
Data systems management	
A. Hardware acquisition	A. Instrumentation and measurement, networking, mass storage, calibration
B. Software engineering	B. Programme development, software support, software documentation, operating systems, database administration;
C. Acquisition and dissemination of data and information	C. Numerical data acquisition and information handling, internet and intranets, quality control, error analysis, filtering
Environmental management	
A. Environmental Impact Assessment	A. Environmental legislation, natural conditions monitoring, people induced changes
B. Watershed management	B. Land degradation, desertification, land use, forestry
C. Environmental quality management	C. Fisheries, nutrients, wetlands' flora and fauna, recreation, ecotourism, freshwater living resources, natural conditions research
Socio-economics and law	
A. Water legislation	A. Legal and institutional framework, constitutional and water rights
B. Water allocation	B. Public participation, conflict resolution
C. Water pricing	C. Water valuation, economic analysis of water development

(*) A more formal set of topical units within BIPs individualized for graduate Hydrologists and Hydrological Technicians is presented in Chapters 3 and 4 respectively.

Environmental management Personnel employed in IWRM in relation to environmental management will necessarily be of different backgrounds in earth sciences, biology, economy, physical sciences and other disciplines. They may receive further education and training, which leads to a profession in the field of environmental management.

This grouping does not mean that these activities are independent and unrelated to the activities carried out by other complementary professionals in water resources and by Hydrologists. Watershed management influences the development of structural measures related, for example, to flood management, and vice versa. The law has a strong influence in the way Environmental Impact Assessments are conducted as do local political and social considerations.

Table 2.1 lists subjects related to these activities within the specialization of environmental management. Once again, each of these combinations (group of activities/subjects) needs specific tools or techniques, which appear in the BIPs, described in Chapters 3 and 4.

Socio-economics and Law Personnel employed in IWRM in relation to socio-economics and law will necessarily come from different backgrounds in social sciences, economy, law, environmental sciences and other disciplines. They may receive further education and training, which leads to a profession in the field of socio-economic and legal aspects related to IWRM. The responsibilities in which they will be involved include: water legislation, water allocation and water pricing.

Once again, this grouping does not mean that these activities are independent and unrelated to the activities carried out by other complementary professionals in water resources and by Hydrologists. Water allocation procedures influence the whole subject of IWRM and the hydraulic works and the hydrological knowledge of a basin should be taken into account when allocating water. The participation of users in the decision making process is relevant to all professionals involved in IWRM but the professionals in socio-economics and law are responsible for elaborating the legal framework in which the decision making process has to be carried out. Table 2.1 lists the subjects of these activities within the specialization of socio economics and law.

CHAPTER 3

BASIC INSTRUCTION PACKAGES FOR HYDROLOGISTS (BIP-HWR) AND COMPLEMENTARY PROFESSIONALS (BIP-DSM, BIP-ENV, BIP-SEL)

Introduction and context

Summary descriptions of syllabi for BIP-HWR subjects

Basic Instruction Packages for complementary professionals
(BIP-DSM, BIP-ENV, BIP-SEL)

Validation, review and accreditation

This chapter describes a framework for Basic Instruction Packages for Hydrologists and complementary professionals. The base topical units are:

- Supporting science and technology;
- General hydrology;
- Data collection and processing;
- Hydrological modelling;
- Environment;
- Water resources management;
- Integrating activities.

A summary table (Table 3.1) presents these topical units and associated subjects for Hydrologists as a general curriculum. The chapter further adapts/modifies this framework for complementary professionals (data systems management, environmental management, and socio-economics and law). Narrative descriptions of the learning objectives and syllabus for each of the several subjects under each topical unit provide guidelines for detailed course development in the context of particular institutional environments and constraints.

The chapter also discusses issues of evaluation and transferability of credits in trans-institutional and trans-national environments. Course validation, assessment and accreditation must be considered for any education and training programme.

3.1

INTRODUCTION
AND CONTEXT

The comments in Chapter 2 highlighted that water resources planning and management is more than ever before a multidisciplinary activity. Prior to the developments of recent years outlined in Section 1.2, the career paths of professionals in the water sector were relatively straightforward. For hydrological specialists, just two grades of Hydrological Technician (HT) and Hydrologist (H) were recognized, the principal difference being that the latter were required to hold a university-level degree or an equivalent qualification. Both categories of personnel were required in addition to have completed Basic Instruction Packages (BIPs) at the appropriate level. The content of such BIPs was laid down in previous editions of these Guidelines. The prerequisites in terms of further education for HT and higher education for H were predominantly from engineering and physical sciences, with, in some countries, strong representation from geography, geophysics and forestry backgrounds. The changes brought about by increasing emphasis on DSM, the increase in public awareness of environmental issues and the spread of privatization in the water sector has created the need for further BIPs to cater to the complementary professional groups working in these areas.

Career paths in the context of IWRM have been summarized schematically in Figure 2.1. The Hydrological Technician (HT) path, further elaborated in Chapter 4, has been divided into two, catering to those specializing in instruments and measurement technology (BIP-HTIMT) and ICT (BIP-HTICT). The Hydrologist (H) path, further elaborated in the present chapter, progresses from the long-established pre-requisite undergraduate degree subjects to a BIP-HWR, which would continue to be provided largely by instructional postgraduate-level Masters degree programmes. In addition, three complementary career paths have been identified for those with specialization in data systems management (BIP-DSM), environmental management (BIP-ENV) and socio-economics and law (BIP-SEL). All four of the BIPs draw upon the same basic topical units and subjects summarized in Section 3.2 but the BIPs for complementary professionals in most cases have a different depth or emphasis to those associated with BIP-HWR.

This differentiation is outlined in Table 3.1, which sets out a matrix of topical units and subjects for BIP-HWR. Table entries for topical units are in terms of credit points (CPs), where one CP is equivalent to 40 hours of effort (not contact time) or approximately one person-week of work (see below). The complementary professional BIPs are differentiated by varying the inputs of different subject areas. The detailed selection may vary in particular applications by individual organizations. For example, BIP-DSM may contain an extra CP for subject 3.1, which would be reflected in an extended syllabus covering (say) more technical subjects such as transmission systems. Similarly, BIP-SEL may have additional CPs on subject 6.1 water resources management, which would cover (say) stakeholder participation issues, either by role-playing or a field exercise.

Neither the credit point allocations nor the specific subjects in Table 3.1 are intended to be prescriptive or, indeed, to correspond to a particular plan of study at a particular institution. Nor are the topical units or subjects necessarily correlated with individual courses. Table 3.1, and the associated syllabi in Section 3.2, represent starting points from which particular institutions or individuals may build their own instructional programmes and the associated learning outcomes assessment according to local constraints.

An individual may pursue training in the various topical units and subjects at different institutions. In this sense, the topical units and subjects of Table 3.1 represent a “portfolio” of training appropriate to the career path; a portfolio whose elements may be acquired in a selective and non-uniform manner, according to local conditions and particular needs.

Transferability of credits between training institutions and recognition of credits by employers or qualifying agencies, will likely involve reconciliation of several credit

systems in use worldwide. Systems are differentiated by their quantification of effort in different instruction and learning modes. For example, in the United States and the United Kingdom, credit is expressed in terms of lecture hours per subject per week, sometimes (but not always) with additional laboratory contact hours explicitly taken into account in the weekly total. By this measure, a typical US engineering college requires the order of $(16 \text{ hours/week/semester}) \times (15 \text{ weeks/semester}) \times (2 \text{ semesters/year}) = 480$ lecture hours per year. Lecture hours are presumed to be correlated with total hours of effort for the course, including laboratory work, tutorials and project work not explicitly reflected in the semester-hour credit.

The credit points of Table 3.1, on the other hand, represent approximately 40 hours of effort (not contact time), i.e. roughly a one person-week of effort. In this system, the total number of credit points per academic year is 50, or 2000 hours of work, and is intended to correspond with a typical one-year taught Masters course. (This figure compares, for example, with the 1650 hours expected of Dutch engineering undergraduates). The total number of hours of work effort during a full academic year for a typical MSc course is generally between 1600 and 2000 hours. The total number of credit points per academic year may be fixed at a number ranging from 40 to 60, the latter being the number used in all universities of the European Union where the harmonized CP system is called the European Credit Transfer System (ECTS).

Reconciliation of the two types of credit systems (i.e. formal contact hours versus hours of effort) requires allocation of credit points to different instruction modes. For example, classroom teaching hours are generally given a heavier weighting than tutored exercises or laboratory hours. As an example only, the following relative weighting factors could be used:

- Classroom teaching: weight of 3
- Seminars and teamwork: weight of 2
- Tutored exercises and laboratory work: weight of 1.5
- Fieldwork: weight of 1

Section 3.2 gives summary descriptions of all the subjects listed in Table 3.1. The syllabi for those subjects whose depth and/or emphasis are not identical for all four BIPS are accordingly broken down into labelled sub-subjects and the selective appearance of these sub-subjects in the different BIPS is also indicated in Table 3.1.

3.2 SUMMARY DESCRIPTIONS OF SYLLABI FOR BIP-HWR SUBJECTS

The summary topical unit descriptions which follow are suggested as starting point guidance for particular organizations, who may find it appropriate to modify them according to their own constraints and needs. Under each topical unit, the suggested subjects may not be appropriate for all four BIPs.

Supporting sciences *Statistics*

Learning objectives: To provide participants with a refreshment of their undergraduate statistics.

Syllabus: Population and samples: types of variables and data; data reduction; frequency and relative frequencies; frequency distributions; statistical descriptors and sample moments; quantiles; characterization of distributions.

Randomness in experiments and sampling: events; elementary probability theory; conditional probability; independence; permutations and combinations.

Random variables and distributions: discrete and continuous distributions; moments; two-dimensional distributions; marginal distributions; conditional distributions.

Testing goodness of fit: statistical hypotheses; error types; significance levels; Chi-square, Kolmogorov-Smirnov and deviation tests.

Comparison of means and variances: tests of significance (normal, Student-t, Fisher-F tests); one- and two-way analysis of variance.

<i>Topical units and subjects</i>	<i>BIP-HWR</i>	<i>BIP-DSM</i>	<i>BIP-ENV</i>	<i>BIP-SEL</i>
1. Supporting science and technology 1.1 Statistics 1.2 Engineering mathematics 1.3 Computer operations 1.4 Technical report writing 1.5 Geology and geomorphology 1.6 Meteorology and climatology 1.7 Economics and finance Topical unit 1 sub-total	6*	6	6	6
2. General hydrology 2.1 Principles of hydrology 2.2 Catchment hydrology 2.3 Agricultural and forest hydrology 2.4 Urban hydrology 2.5 Hydrogeology and groundwater exploration 2.6 Groundwater Flow 2.7 River Hydraulics Topical unit 2 sub-total	11	10	10	10
3. Data collection and processing 3.1 Data information systems 3.2 Earth observation systems 3.3 Hydrological statistics 3.4 Meteorological observations 3.5 Hydrometry 3.6 Hydrological network design Topical unit 3 sub-total	6	10	5	5
4. Hydrological Modelling 4.1 Numerical methods 4.2 Hydrological modelling 4.3 Hydrological forecasting 4.4 Surface Water modelling 4.5 Groundwater flow modelling 4.6 Contaminant transport modelling Topical unit 4 sub-total	7	5	4	3
5. Environment 5.1 Surface water chemistry and biology 5.2 Environmental Impact Assessment 5.3 Environmental policy 5.4 Groundwater chemistry 5.5 Water pollution Topical unit 5 sub-total	4	3	8	5
6. Water resources management 6.1 Water resources management 6.2 Water resource system operation 6.3 Institutional arrangements 6.4 Water law Topical unit 6 sub-total	3	3	4	8
7. Integrating activities 7.1 Team-building exercise 7.2 Fieldwork 7.3 Field excursions 7.4 Individual study Topical unit 7 sub-total	13	13	13	13
Total credit points	50	50	50	50

* Credit point allocation in units of 40 hours of effort (see Section 3.1)

Table 3.1—Matrix of topical units and subjects for BIP-HWR

Engineering mathematics *Learning objectives:* To provide participants with a refreshment of their undergraduate mathematics.

Syllabus: Fundamental concepts in analysis: functions of one variable, continuity, limits, derivatives, integration; infinite series; Taylor expansion, ordinary differential equations; Laplace transforms and applications.

Linear algebra: matrices, systems of linear equations, inverses, determinants; vector spaces, sub-spaces, orthonormal bases and orthogonal projections; applications to least squares; eigenvectors and diagonalization.

Introduction to Fourier analysis.

Functions of several variables: partial differential equations and applications.

Computer operations *Learning objectives:* To assist participants to use the local computer network and the most commonly used software packages.

Syllabus: Introduction to computer and network technology: the local network; wide area networks; internet.

Operating system and application software: basics of MS Windows and MS DOS; file systems; application software overview.

Software instruction: standard tools; word processors and spreadsheets; data exchange among different applications.

Technical report writing *Learning objectives:* To assist participants in preparation of a structured technical report, including proper literature references and to perform a technical presentation.

Syllabus: Development strategies: forming an outline; building a case.

Scan reading and literature study: basic features of a report.

Skill in writing: paragraph writing; topic statements and patterns.

Production: editing for emphasis; punctuation.

Scientific and professional literature: types of publications; citations and references; exercise in database and library catalogue literature search.

Geology and geomorphology *Learning objectives:* To introduce participants to the basic terminology and concepts of geology, and its relevance to the water environment. In particular, the participant should be able to read geological and geomorphological reports, maps and cross-sections, and interpret these in terms of hydrological implications.

Prerequisites: Working experience with topographic maps.

Syllabus: Introduction to geology: the earth structure including core mantle and crust of the earth; plate tectonics theory and consequences.

Geological processes: volcanism and intrusive processes; weathering, erosion, transport and sedimentation; formation of carbonate rocks; metamorphism.

The geological time scale: pre-Cambrian, Paleozoic, Mesozoic and Cenozoic periods; main geological features in the successive periods; rock dating by fossil content and other methods; type localities and naming of geological formations.

Structural geology: anticlines, synclines and monoclines; normal, reverse and other types of faults; mechanisms that determine structural geology.

Quaternary geology: prevailing processes in river valleys, coastal basins and tectonic basins; typical rock compositions in these valleys and basins; the formation of soils; typical features in different continents.

Examples of geological maps for selected areas.

Exercise in map interpretation in which geological maps will be reviewed: lithological interpretations; structural analysis of an area; hydrological implications.

Mineral and rock types: crystal classes and types of minerals; definition and classification of rocks; hands-on introduction exercise in mineral and rock determination.

Evolution of land form: basic theory of landscape forming processes; endogenic (geologic) forces acting on the earth's surface; exogenic (climatic) forces acting on the earth's surface.

Weathering and erosion: typical landscapes by physical weathering and chemical weathering formation processes; erosion and river work as geomorphological mechanisms; geomorphology of specific climatic zones; geomorphology of limestone areas.

Meteorology and climatology

Learning objectives: To increase participants' understanding of the principles of atmospheric physics, general circulation patterns and weather systems and to evaluate the role of evaporation in the climatic system and in particular in atmosphere – land-surface interactions.

Prerequisites: Engineering mathematics and principles of hydrology.

Syllabus: Atmosphere physics: general introduction; atmospheric gas laws; phase changes of water; psychrometer formula; moisture variables; thermo-dynamics of vertical atmospheric motion; radiation.

Micrometeorology: vertical turbulent transport; advection and exposure; mass transfer and energy balance evaporation theories.

Meteorological observation: general problems; requirements for stations.

General meteorology: vertical stability; precipitation formation; artificial control of precipitation; general circulation; large-scale weather systems; meteorological forecasting possibilities.

Climatology: synthetic parameters and classification; moisture indices; seasonal circulation patterns; local winds; diurnal and annual courses; influences of latitude and topography; climatic periodicities and changes.

Hydrological processes in the context of large-scale climatology and introduction to the General Circulation Models.

Economics and finance

Learning objectives: To introduce participants to the basic concepts of economic and financial administration and their use these within engineering projects and organizations.

Syllabus: Basic concepts: economy and the market concept; demand and supply; classification of goods; costs and benefits. Cash flow analysis: project cash flow tables; financial versus economic evaluation; financial and economic costs; exercises.

Economic evaluation of projects: discounting; evaluation criteria; tariffs and water prices; projects as vehicles for economic development; transferring projects to the private sector; exercises.

Financial management and administration: concepts in accounting; financial recording and reporting; annual balances; exercises.

*General hydrology
Principles of hydrology*

Learning objectives: To enhance participants' understanding of the basic principles of hydrology, the establishment of water balances and the estimation of its components, and the performance of hydrological data analysis.

Prerequisites: Statistics and engineering mathematics.

Syllabus: Development of hydrology: the hydrological cycle; catchments; water balance; influence of man on the hydrological cycle; hydrological data.

Precipitation; formation of precipitation; measuring devices; rainfall depth, duration and intensity; areal rainfall; rainfall data screening; depth duration frequency

curves; analysis of extreme rainfall events; mixed distributions; probable maximum precipitation; analysis of dry spells.

Evaporation from open water, intercepted water and bare soil; transpiration; actual and potential evapotranspiration; factors affecting evapotranspiration; empirical formulae and physically based theories to estimate evapotranspiration; methods to estimate potential evapotranspiration (Penman, Monteith, Makkink, Blaney & Criddle, Thornthwaite); calculation examples; evaporation measurement.

Groundwater resources; occurrence of subsurface water; infiltration; factors governing infiltration; measuring techniques; formulae for estimating infiltration; water in the unsaturated soil; readily available soil moisture; occurrence of water in the saturated zone; types of aquifers; groundwater flow and storage; Darcy's law and equation.

Surface water resources; determination of runoff; open channel flow; equation of Manning; rating curves; flood surveys; hydrograph analysis; factors affecting hydrograph shape; flow duration curves; flood frequency analysis; lack of data.

Rainfall-runoff relations; short duration peak runoff; long duration catchment yield; deterministic catchment models.

Catchment hydrology

Learning objectives: To assist participants to master the more advanced applications and techniques for describing the relationship between rainfall and streamflow, use of remote sensing techniques at the catchment scale, flood routing in open channels and reservoirs, storage-yield relationships of reservoirs and the ungaged catchment problem.

Prerequisites: Principles of hydrology.

Syllabus: Introduction: the hydrological cycle; water balances.

Measurement of surface flows: hydraulic controls and channel geometry; the rating curve; logarithmic plotting; effect of water surface slope; extrapolation of rating curves; introduction to artificial controls and gauging structures; use of remote sensing in quantifying precipitation at the catchment scale.

Rainfall-runoff relationships: historical background; factors affecting streamflow; the unit hydrograph method; design flood estimation; the US SCS method; introduction to fluvial geomorphology and the Geomorphological Instantaneous Unit Hydrograph; the systems approach: analysis and synthesis; linear and non-linear models; lumped and distributed models.

Regional analysis: synthetic unit hydrograph methods; definition of regions; regionalization of annual flood quantiles.

Flood routing in open channels: complete dynamic models; approximate routing techniques: kinematic wave and diffusion analogy models; storage routing methods: Muskingum and Muskingum-Cunge methods.

Reservoirs: flood routing through reservoirs: full tabular and approximate routing methods; importance of choice of control structure; types of reservoirs; storage-yield analysis: residual mass, cumulative mass methods; sequent peak algorithm; critical period analysis; probability transition matrix methods.

Climate, land use and the flow regime: global climate changes and their implications; land-use changes and their effects on the flow regime; climate impact modelling.

Agricultural and forest hydrology

Learning objectives: To enhance participants' understanding of the importance of physical and chemical soil properties on the availability and quality of soil water so that they are able to design a simple sub-surface drainage system and to compute crop and irrigation water requirements.

Prerequisites: Principles of hydrology and groundwater flow.

Syllabus: Soil science: physical and chemical properties of soils; soil formation; mapping and classification.

Physics of soil moisture; soil water potential, soil moisture content, hydraulic conductivity; equations of unsaturated flow; infiltration and capillary rise.

Irrigation and drainage: methods of surface irrigation; equations for sub-surface drainage; measurement of hydraulic conductivity.

Crop water requirements: leaching requirements; irrigation efficiencies; calculation of project supply requirements.

Urban hydrology

Learning objectives: To expose participants to the problems associated with the water cycle in urban and urbanizing areas.

Prerequisites: Principles of hydrology, catchment hydrology and hydrological modelling.

Syllabus: Urbanization and urban hydrology; urban microclimate; meteorological aspects of drainage design: rainfall depth-duration-frequency relationships, design storm profiles, areal reduction factors.

Stormwater drainage design: Rational Method, Typical Storm Methods, Transport and Road research Laboratory Hydrograph Method, Wallingford Procedure. Evaluation of existing drainage systems; levels of service.

Stormwater management; the internal and external drainage problems and their interaction; structural methods of flood control: flood storage reservoirs, channelization, water quality and environmental considerations. Integrated catchment planning.

Hydrogeology and groundwater exploration

Learning objectives: To familiarize the participants with the various concepts and techniques applied to the analysis of groundwater systems, the exploration for groundwater resources in a variety of natural conditions, and the investigation of the properties of aquifers and the construction of wells.

Prerequisites: Basic knowledge of geology.

Syllabus: Introduction: definition and relevance of hydrogeology; history and future outlook; scope of the topic.

Origin and occurrence of groundwater: hydrological cycle; surface water, soil water and groundwater systems. Groundwater systems terminology: density and viscosity; openings in rocks; porosity and permeability; aquifers and aquitards; boundaries.

Formation of groundwater systems: groundwater systems in unconsolidated sediments; aquifers in consolidated sediments; aquifers associated with metamorphic rock; aquifer systems in igneous rocks.

Development of groundwater resources: groundwater planning; field investigations; consequences of groundwater abstraction; concept of potential and optimum withdrawals (safe yields); artificial recharge.

Regional groundwater flow in groundwater systems: basic equations; the concept of hydraulic head; groundwater flow in hard rock; transmissivity and vertical resistance; the Darcy's Law equation and regional flow; groundwater maps and flownets; regional numerical models.

Groundwater balances: the components of the water balance; determination and checking the components; effects of changing the balance; examples of water balances for groundwater systems.

Surface geophysical methods: geo-electrical methods including theory, resistivity interpretation, hydrogeological interpretation, field procedures; electro-magnetic methods including theory, interpretation techniques and surveying methods; other geophysical methods.

Exploration drilling: review of drilling methods; rock and groundwater sampling procedures; data processing; selection of drilling method. Geophysical logging:

description of spontaneous potential; resistivity, and gamma logging; interpretation of logs and resistivity calibration.

Well design: screen and gravel pack design; grain size analyses; design of pump housing and sanitary protection; use of packers; wells with an open intake; well completion; well development; clogging; well maintenance and rehabilitation.

Pumps: types of pumps; selection of pumps.

Pumping tests in groundwater exploration: definitions and classification of pumping tests; field procedures; selection of tests; step-drawdown tests; determination of borehole yield and efficiency; constant yield tests.

Groundwater flow

Learning objectives: To familiarize participants with steady and non-steady groundwater flow calculations, including flow towards wells in aquifers and analytical solutions for evaluation of pumping tests and the principles of salt-water intrusion in coastal aquifers.

Prerequisites: Engineering mathematics.

Syllabus: Review of geohydrology: groundwater systems; hydrological stresses; steady and unsteady flow. Mathematical background for steady groundwater flow: Darcy's Law; mass balances in a 3-dimensional groundwater system.

Analytical approach: confined, unconfined and semi-confined flow.

Numerical approach: elements; cells; sets of linear equations.

Analytical solutions to steady radial well flow: confined, unconfined and semi-confined conditions.

Principles of advective transport for radial and 1-dimensional flow conditions.

Theory of unsteady groundwater flow: storage in confined and unconfined aquifers; basic differential equations.

Cases of unsteady flow: analytical solutions for 1-dimensional flow; analytical solutions for radial flow towards a well.

Introduction to salt water intrusion: social relevance in many coastal zones in the world.

Introduction to the theory of density dependent groundwater flow; mathematical description of the governing partial differential equations; analogy with heat transport.

Introduction to the theory of an interface between fresh and saline groundwater; analytical interface concepts.

Van Dam's unconfined, confined and semi-confined aquifers, upcoming problem of saline groundwater; introduction to the theory of freshwater heads.

River hydraulics

Learning objectives: To familiarize participants with those aspects of hydraulics and the transport of sediments that are necessary in the analysis of fluvial systems.

Prerequisites: Engineering mathematics and principles of hydrology.

Syllabus: Appearance of rivers: variety in rivers; factors affecting river behaviour.

Functions of rivers and river water: drainage; transport; power; irrigation; water supply; recreation.

General flow phenomena: channel and pipe flow; different types of flow regimes; flow transients.

Human interference: effects of control measures, catchment changes, withdrawal and drainage, power generation, mining and pollution; contradictory impacts and need for management.

Basic processes and parameters: motion and sediment transport; physical parameters and bed properties; timescales.

Data collection, processing and interpretation
Data information systems

Learning objectives: To provide participant with a working understanding of hydrological data information systems. To introduce participants to the principles of geographical information data processing, storage and analysis so that they are able to use geographical information systems (GIS) as a tool for water resources applications.

Prerequisites: Geology, geomorphology and principles of hydrology and working experience with topographic and thematic maps.

Syllabus: Monitoring systems, recording and data transmission.

General principles of data management and data information systems for water management.

Data processing: entry and editing, validation, correction, completion, transformation, compilation and analysis; functional requirements for database management and processing systems.

Geographical Information Systems: principles of geographical information storage and manipulation; GIS operation tutorial; GIS analysis.

Reporting: presentation of data using graphics; reports.

The use of database information systems: stand alone and in relation to simulation models and GIS.

Data exchange between models, geographical information systems, spreadsheets and databases.

Earth observation systems

Learning objectives: To introduce participants to the principles of stereoscopic photogrammetry, satellite imagery and radar detection of precipitation and to conduct a hydrological survey using these techniques.

Prerequisites: Physics of optics and electromagnetic radiation.

Syllabus: Basic photogrammetry: types of aerial photographs; geometrical properties of aerial photographs; differences in mathematical properties of vertical aerial photographs (central projection); stereoscopic vision; height exaggeration, parallax and floating mark. Film and filter properties of panchromatic films; basic qualities of radar observation; infrared photography; false colour photography; satellite imagery; scale problem and applications.

Qualitative and quantitative methods: importance of photo and image scale, emulsion type etc.; simple photogrammetric and satellite imagery exercises; influence of distortion of the model for interpretation; main geomorphological facies types.

Remote sensing of hydrometeorological variables such as precipitation estimation using weather radar and satellite data and soil moisture estimation using passive and active microwave sensors; sensing of earth surface properties such as land cover with multi-spectral satellite remote sensing etc.

Hydrological statistics

Learning objectives: To enhance participants' knowledge of quality assurance of data sets, frequency analysis and the regionalization of hydrological variables, and their awareness of the various techniques for the analysis and generation of hydrological time series.

Prerequisites: Statistics and engineering mathematics.

Syllabus: Homogeneity and consistency in data sets; data screening techniques: testing for linear trend, differences in means and variances of sub-sets and independence.

Frequency analysis: statistical descriptors; risk and return period; methods for fitting frequency distributions: methods of moments and maximum likelihood and graphical methods; types of distributions: binomial, geometric Poisson, normal, log-normal, general extreme value, Pearson family, exponential; regionalization of hydrological variables: identification of regions; derivation of regional frequency distributions.

Introduction to time series analysis: stochastic hydrology; prescriptive models of hydrological variables; stochastic processes and their relevance in hydrology and water resources engineering; random number generation.

Pre-whitening: trend, periodicity and stochastic components of time series; autocorrelation analysis and spectral analysis; harmonic analysis; ARIMA models; diagnostic checking.

Univariate and multivariate modelling of hydrological time series; the Hurst phenomenon; linear models of dependence; disaggregation techniques; generation of synthetic rainfall sequences: Bartlett-Lewis and Neyman-Scott processes.

Spatial description: spatial hydrological and hydrogeological variables; spatial variability; trend surface with polynomial functions; ordinary kriging; intrinsic hypotheses; the variogram; ordinary kriging estimation; ordinary kriging system; estimation of variance; case studies.

Meteorological observations *Learning objectives:* To enable participants to set up a climatological field station for hydrological purposes and to carry out observations and analyse the data.

Prerequisites: Basic knowledge of meteorology and hydrology is advantageous.

Syllabus: Meteorological instruments: response theory, thermometers, radiation meters, hygrometers, snow and dew measurement, wind meters, radar, radiosonde; principles of observation and recording for attended and unattended station.

Observation exercises: measurements of temperature, humidity, solar radiation and wind; keeping, checking and adjustment of records.

Hydrometry *Learning objectives:* After finishing, participants are able to select appropriate sites and techniques for measuring water levels, discharges and sediment transport.

Prerequisites: Principles of hydrology.

Syllabus: Water levels: water level gauging station and the selection of sites; types of gauges and recorders; design of the stilling well and accuracy of water level measurement. Bed levels: position fixing including GPS and the use of rangefinder and sextant; sounding of cross-sections including the use of sounding instruments.

Discharge measurements: classification of methods; special attention for the most important methods: the velocity-area method including the ADCP, the dilution method, the stage-discharge method and the acoustic method.

Sediment transport: Classification of sediment transport; methods and instruments to measure bed load, suspended load and wash load; bottom sampling; grain sizes.

Flow measuring structures: classification of structures; selection of type; head-discharge equations; accuracy in the evaluation of discharge.

Hydrological network design *Learning objectives:* To provide participants with a clear appreciation of the importance of collecting hydrological data in a systematic and cost-effective manner and methods for designing a network of hydrological observations.

Prerequisites: Principles of hydrology and statistics.

Syllabus: Objectives and principles of network planning and design. Characteristics of hydrological elements and their influence on network design: precipitation and evaporation; surface runoff; groundwater; water quality.

- Techniques for network design: systems analysis and design theory; statistical sampling and optimization; regionalization. Kriging based methods for the design of network density; time series analysis for the determination of sampling frequency.
- Modelling Numerical methods* *Learning objectives:* After finishing, participant understand the most common numerical solution procedures and are aware of the constraints in model applications.
- Prerequisites:* Engineering mathematics.
- Syllabus:* Introduction: review of models, equations and numerical solutions.
- Typical numerical methods in hydrological modelling: finite differences; finite volumes; finite elements.
- Application of numerical methods to one-dimensional flow problems.
- Hydrological modelling* *Learning objectives:* To provide the participants with a thorough background in the various aspects of modelling, model approaches and modelling studies.
- Prerequisites:* Principles of hydrology and catchment hydrology.
- Syllabus:* Hydrological models and hydrological systems: what is a hydrological model? The terrestrial hydrological system; why model the hydrological system? Types of hydrological models: functional classification; structural classification; classification by level of disaggregation.
- Model selection: criteria for selection; complex versus simple models; modelling under different climatic and physiographic conditions. Calibration of model parameters: purpose, approaches to and problems in calibration. Model performance: aims of verification studies; objective functions; goodness-of-fit statistics; sensitivity of output to input; errors in modelling.
- Issues in modelling: should new models be developed? Emerging trends in modelling – hydrological and institutional; interfacing models with other technologies; ethics in modelling.
- Hydrological forecasting* *Learning objectives:* To expose participants to the techniques involved in flood forecasting, control and warning.
- Prerequisites:* Catchment hydrology and hydrological modelling.
- Syllabus:* Why forecast floods?
- Flood as a natural disaster; objectives of forecasting.
- Causes of floods: precipitation, snow and ice melt induced floods; dam breaks. Flood intensifying factors: climate, catchment and channel network characteristics.
- Forecasting and warning networks: conventional networks; remote sensing principles; radar; telemetry; synoptic forecasting.
- Flood mitigation methods: structural and non-structural. Flood damage and loss assessment.
- Surface water modelling* *Learning objectives:* To provide the participants with a working knowledge of hydrodynamic modelling.
- Prerequisites:* Principles of hydrology, river hydraulics and numerical methods.
- Syllabus:* Principles of hydrodynamic flow: mass equation; momentum equation, Chezy formulae.
- Hydrodynamic parameters: Manning and Chezy resistance; flow and storage profiles, bed and surface slope.
- Numerical schemes: Leap-frog and central difference Preissmann schemes; accuracy and stability.

Schematization of simple and complex river and canal systems: nodes, sections, cross-sections. Hydraulic and model aspects of structures: weirs; culverts; siphons; pumps.

Groundwater flow modelling

Learning objectives: To enable the participants to design and evaluate groundwater models.

Prerequisites: Groundwater flow, hydrogeology and groundwater exploration, and numerical methods.

Syllabus: Principles: mass balance equation; Darcy's Law; multi-dimensional and multi-layer systems; hydrogeological parameters. Spatial and temporal distribution of the hydrological parameters: types of hydrological stresses.

Familiarization with the calibration and verification of groundwater models.

Conceptual models: schematization of groundwater systems; geohydrological assumptions; constant head and flow controlled boundaries; mixed boundary conditions; internal boundaries.

Numerical modelling approaches: finite elements; finite differences; cell approach and polygon-based integrated modelling. Modelling of steady and unsteady flow in a multi-dimensional space. Application of a multi-layer system using a 3-dimensional cell-based finite difference code.

Contaminant transport modelling

Learning objectives: To enhance participants' understanding of contaminant transport processes and their ability to use numerical models for contaminant transport simulation both in surface water and groundwater environments.

Prerequisites: Numerical methods; surface water modelling; water pollution; groundwater flow modelling.

Syllabus: The theory of dispersion in surface water bodies: dispersion phenomena; mechanisms of dispersion; coefficients of dispersion; mathematical formulation of hydrodynamic dispersion. Analytical models: mono-dimensional and bi-dimensional horizontal models.

Numerical methods for transport: dispersion-free approximation; pathlines and travel times; finite difference method; finite element method; method of characteristics, applicability of transport models.

Processes: DO modelling; re-aeration, BOD decay, nitrification, sediment oxygen demand, oxygen production by algae and macrophytes; Streeter-Phelps model; eutrophication modelling of algal growth, nutrient cycling, nutrient uptake kinetics, P partitioning, sediment water exchange.

Environmental aspects Water chemistry and biology

Learning objectives: To introduce the participants to the basic chemical and biological processes in aquatic systems.

Syllabus: Water chemistry: structure and properties of matter; the periodic system; chemical calculations; chemical equilibrium; pH; strong and weak electrolytes; precipitation reactions; solubility product; redox reactions in the environment.

Aquatic ecosystems: effects of thermal stratification on water quality; photosynthesis and respiration; eutrophication; the Vollenweider model.

Aquatic sediments: environmental factors in sediment-water exchange; pore water profiles; estimation of sediment-water exchange fluxes.

Environmental Impact Assessment

Learning objectives: To provide participants with an overview of techniques of Environmental Impact Assessment.

Syllabus: Water quality: relationship between quality and water use purposes; natural and man-induced changes in water quality; planning and management tools for improving water quality.

Case studies: environmental aspects of dam construction; integration of ecological aspects in river-reservoir projects.

Environmental policy *Learning objectives:* To enhance participants' understanding of the technical background to policy formulation.

Syllabus: Impact of climatic change: consequences for development policy and land use planning; tension in politically shared river basins.

Major complex developmental/environmental policy issues: sustainable development; demand on resources; deforestation and rural deterioration; bad land management and practices.

Stages in environmental policy making: problem recognition; awareness building; policy formulation; procedures; maintenance and control.

Groundwater chemistry *Learning objectives:* To assist the participants in applying the principles of hydro-chemistry in order to assess groundwater quality in a variety of situations and conditions.

Prerequisites: Surface water chemistry and biology, geology and geomorphology, and hydrogeology and groundwater exploration.

Syllabus: Introduction: units of analyses; accuracy of analyses; electro-neutrality.

Precipitation and groundwater: precipitation chemistry; from precipitation to groundwater; trends in water quality; concentration limits.

Hydrolysis of silicate minerals: reaction equations; common examples.

Dissolution of carbonate rocks: equilibrium constant; soil moisture chemistry and CO₂ pressure; open and closed system dissolution of calcite; calcite/dolomite dissolution in the field; examples of field studies.

Cation exchange: cation exchange in the salt-freshwater environment; adsorbents in soils and aquifers; cation exchange equations; chromatography.

Oxidation and reduction: basic theory; pe-levels for redox reactions; construction of pe-pH diagrams.

Field measurement and interpretation of data: groundwater sampling; electrical conductivity; temperature; individual ions; pH measurement; data processing.

Water pollution *Learning objectives:* To enable participants to understand groundwater quality standards, the different sources of pollution, the most important processes affecting groundwater quality and measures to protect groundwater resources.

Prerequisites: Surface water chemistry and biology and groundwater flow modelling.

Syllabus: Processes determining groundwater quality (hydrological, chemical, physical and biological) and outline of water quality standards.

Sources of diffuse pollution. Environmental sources: salt water intrusion (salt) and surface impoundments (nutrients and organic compounds). Agricultural sources: pesticides (chemicals); fertilizers (nutrients); animal manure (nitrates, phosphates, bacteria, viruses), irrigation (salt).

Sources of point pollution. Domestic sources: sewers (biological materials); septic tanks (organic compounds); storage tanks (nutrients); landfills. Industrial sources: industrial wastes (heavy metals); mining (radionuclides); radioactive waste disposal; septic and storage tanks.

Processes affecting water quality and pollution. Mass transport: convection, dispersion and diffusion. Chemical mass transfer: radioactive decay; sorption, dissolution/precipitation; acid/base reactions; complexation; hydrolysis/substitution; redox reactions (biodegradation). Biological mediated mass transfer: biological transformation.

- Prevention of and protecting against water pollution. Assessment of water vulnerability, taking preventive measures including the design of groundwater protection zones. Design and implementation of clean up and isolation measures.
- Water resources management* *Learning objectives:* To introduce participants to modern approaches to water resources planning and management, including the assessment of demands and tools for planning and management.
- Prerequisites:* Statistics, engineering mathematics and economics and finance.
- Syllabus:* Water as a general resource: availability and use; previous practices in water resources planning and management; current issues and definitions.
- Water in the market economy: competition, economies of scale and scope, private and public goods; subtractability and excludability; externalities; the role of government; provision and production of services; analytical framework of water resources management; supply-driven and demand-driven systems; setting of tariff levels; decentralization and stakeholder participation; water quality, health and environment.
- Public water supply: population forecasting; estimation of demands for public water supply; extrapolative methods and the component method.
- Flood alleviation: benefits – tangible, intangible, direct and indirect; influence of flood warning schemes; evaluation of urban and rural flood alleviation schemes.
- Hydropower planning: estimation of power demand; flow-duration and power duration curves; preliminary costing of schemes.
- Agriculture: soil-water-plant relationships; cropping patterns; water-yield relationships; irrigation requirements and scheduling; leaching requirements; farm management; importance of drainage.
- Analysis of water resources systems: planning tools descriptive/simulation and programming/ optimization methods; case studies.
- Water resources system operation* *Learning objectives:* To provide participants with a basic knowledge of approaches for the design and operation of water resources systems.
- Prerequisites:* Water resources management.
- Syllabus:* Computational framework for water resources planning: decision support systems, simulation and optimization models.
- Interpretation of model results and translation into plans.
- Management information systems.
- Planning under uncertainty: information requirements, model uncertainty, sensitivity analysis, scenario formulation.
- Institutional arrangements* *Learning objectives:* To enhance participants' understanding of the institutional context within which water resources planning and management is executed.
- Prerequisites:* Water resources management and water resources system operation.
- Syllabus:* The role of government. National hierarchy. Water rights. Cost recovery.
- Institutional arrangements: evolution and comparison of different models: British, French and Dutch.
- Water law* *Learning objectives:* To provide participants with a basic insight into the need and format of laws pertaining to the development and use of water resources.
- Prerequisites:* A general understanding of law, legislation, common law and traditions.
- Syllabus:* Physical contexts relevant to water law and relevant socio-economic context.
- Origins, history and systems of water law.

Water resources administration including administration of international water resources.

Water resources planning and water law.

International water resources law. Current trends in water law and administration.

Integrating activities
Team building exercise

Learning objectives: To build an appreciation among the participants of the functioning of multidisciplinary project teams.

Syllabus: The participants are set to work in a team of specialists. Activities include planning of activities, communication with others, and reporting. The exercise provides ample opportunity to apply the theory, mastered earlier during the programme, and to integrate this into a problem-orientated approach. The participants work in small groups on a particular case. The lecturers introduce the case and streamline further activities, which to a large extent are carried out independently by the participants. Finally, each participant gives an oral presentation on one of the aspects in the case.

Fieldwork

Learning objectives: In order to acquire practical experience in the analysis of hydrological systems, the participants carry out a fieldwork in a suitable nearby location.

Syllabus: The fieldwork concentrates on the various aspects of the local hydrological regime, integrating field observations of the geology and geomorphology in combination with surface and groundwater data collection and analysis. Special reference is made to current environmental and water resources management issues in the area as well as to the interaction between surface and groundwater in both the qualitative and quantitative sense.

Field excursions

Syllabus: Several one-day fieldtrips in the host country and a two-week excursion to other neighbouring countries.

Individual study

Syllabus: An individual study on a chosen topic is carried out under supervision of a core staff member. The participants produce a report and an oral presentation is given during the general examination at the end of the academic year.

3.3 BASIC INSTRUCTION
PACKAGES FOR
COMPLEMENTARY
PROFESSIONALS
(BIP-DSM, BIP-ENV, BIP-SEL)

The BIP descriptions in Section 3.2 are specifically focussed on the needs of the Hydrologist, but also serve to provide elements of the base curricula for the three other complementary professionals (DSM – data systems management; ENV – environmental management; SEL – socio-economics and law), as shown in Table 3.1. Although it has not been usual practice to associate the training of complementary professionals so closely with that of Hydrologists, it is clear from the discussions in Chapter 2 that such association is becoming increasingly necessary. In some instances the curricula for the complementary professionals require merely a change of focus or depth from those destined for hydrologists.

Data systems management
(DSM)

From the beginning of systematic hydrometric measurement, heavy reliance was placed in the continuous recording of both water levels and rainfall depths on instruments equipped with pens moving over paper charts. The raw data was therefore difficult to store and tedious to extract for analysis. The progress achieved with solid-state technology has been such that modern instruments record in computer-compatible formats that can be accessed directly by modelling systems software. Furthermore, the development of Geographical Information Systems (GIS) has enhanced professional capabilities in spatial analysis far beyond the scope of conventional mapping systems. With the ready availability of personal computers and local area networks, technical professionals in the water sector are required to become increasingly computer literate. However, the complexity of modern operating systems, databases, GIS systems and communications and instrument technology is such that dedicated professionals are

increasingly being recruited to service organizational requirements in information and communications technology. This trend is likely to continue with advances in informatics in such areas as expert systems, case-based reasoning and knowledge management.

Although there are undoubtedly gains in efficiency to be achieved from the implementation of DSM at all levels in a water sector organization, a realistic appreciation of potential disadvantages should be maintained. A simple, but fundamental, example may be found in the application of preliminary data screening to raw hydrometric records. Whereas a pen trace on a chart in the past provided a good first visual impression that an instrument was functioning correctly, specific procedures must now be implemented to establish the veracity of a coded computer recording. Moreover, interpretation of the results from data screening requires a significant amount of domain knowledge on the part of the analyst. In these circumstances, conventional DSM skills must be supplemented by a training programme in water sector applications.

Environmental management (ENV)

The basic instruction package for environmental management requires the same emphasis on fundamentals in supporting science and technology as BIP-HWR. Environmental programmes may relax slightly the need for some of the details involved in general hydrology and hydrologic modelling, since this career path does not normally require knowledge of the details of geophysical methods for sub-surface investigation, mathematical models of groundwater modelling, quantification and modelling of surface water flow, etc. On the other hand, environmental programmes may require increased emphasis on data information systems, GIS, remote sensing, etc. in support of environmental assessment and inventories. In addition, environmental programmes clearly require more depth in training related to environmental chemistry and biology, environmental impact, environmental policy, etc.

Socio-economics and law (SEL)

The basic instruction package for socio-economics and law requires the same emphasis on fundamentals in supporting science and technology as BIP-HWR. In relation to data collection and processing the needs are less important and this is reflected in the suggested distribution of credits presented in Section 3.1. Since this career path normally requires only the use and understanding of the results of models, the emphasis on hydrological modelling is suggested to be less. On the other hand, socio-economics and law programmes may require more emphasis on water resources management, particularly in water legislation, water rights and also on economic aspects that are relevant to the process of water allocation. The need to interact with other professionals in the field of IWRM is also suggested in this BIP and could be covered under “Integrating Activities”.

3.4

VALIDATION, REVIEW AND ACCREDITATION

The last two decades of the 20th century saw increasing emphasis on quality assurance in further and higher education, worldwide. Issues of quality assurance are explored in general terms in Appendix 1. Within the European Union, the Bologna Agreement of 1999 provided the basis for member states to move towards a unified structure for Bachelor and Master programmes, with an implicit understanding that quality assurance systems would eventually become trans-national. In discussing such systems, one should take care to distinguish between validation and review by academic bodies, usually operating on behalf of the Ministry of Education or its equivalent, and professional accreditation of degree courses. The former now forms a well-established part of the routine for the academic staff concerned with the delivery of a degree course, usually over a five-year cycle. Following the production of a self-assessment report, independent external validators review the course content and delivery, recruitment and completion rates along with staff profiles and research activities in support of the academic programme.

Professional accreditation has many aspects in common with academic reviews, but places greater emphasis on the preparation (“formation”) for entry into a

specific profession, such as civil, mechanical, electrical and electronic or chemical engineering. For example, in the United Kingdom, the chartered engineering institutes, which regulate the professional competence of practicing engineers, play a role in accreditation of engineering degree courses at Bachelors level. In the USA, a comparable activity is undertaken by the Accreditation Board for Engineering and Technology (ABET), an organization founded in 1932. During the period 1997–2001, ABET altered its emphasis from assessment of teaching (input) to assessment of learning outcomes (output) as the basis for accreditation.

National systems of (academic) validation and review may differ in their detailed procedures, but overall objectives, i.e. assurance of programme relevance and integrity of output standards, are broadly similar. The provisions of validation and review naturally extend to the postgraduate/post-experience Master level degree courses of the type that would conform to the BIPs outlined in the previous sections. Such activity would also extend to issues of professional relevance, although the review process rarely includes professional bodies explicitly. The courses that are based on BIPs therefore carry the implicit caveat that they should have successfully undergone the appropriate national process of validation and review. In the future, if the current plans for trans-national quality assurance by UNESCO in the form of the Global Forum on Quality Assurance and Accreditation in Higher Education are brought to fruition, it can be expected that such courses would wish also to achieve international recognition.

CHAPTER 4

BASIC INSTRUCTION PACKAGE FOR HYDROLOGICAL TECHNICIANS (BIP-HTIMT, BIP-HTITC)

Introduction and context

Basic Instruction Packages for Hydrological Technicians

Description of BIP-HT topical units

This chapter describes a framework for basic instruction packages for Hydrological Technicians in two branches of specialization. The topical units are:

- Introduction to hydrological processes;
- Mathematics;
- Statistics;
- Computer operations;
- Surveying, map reading and photo-interpretation;
- Electrical principles for measuring techniques;
- Meteorology;
- Hydraulics;
- Hydrometry;
- Hydrogeology;
- Water quality;
- Analysis of hydrological data;
- Data storage and retrieval;
- Instruments maintenance.

These topical units are provided as a general curriculum (see Table 4.1). The learning objectives and syllabus for each of the several subjects under each topical unit are briefly elaborated in narrative form as a guideline for detailed course development in the context of particular institutional environments and constraints.

Mathematics *Learning objectives:* To provide participants with the necessary knowledge of the mathematical tools that will be used in other subjects.

Syllabus: Algebra (logarithms; exponential logarithmic equations; solution of linear equations in two variables; quadratic equations, algebraic and graphical solution; concept of the function of a and its graphical representation: plotting a graph, plotting on log-log and semi-log graphs, linear equation and straight line graph).

Plane and solid geometry (geometric loci; triangles; regular polygons and their properties; circles arcs and segments; definition and value; angle between a straight line and a plane: trihedrons; polyhedrons; prisms; pyramid; frustum of a pyramid; cylinder; cone; frustum of a cone; surface, units, areas and volumes).

Plane analytic geometry (Cartesian, rectangular and polar coordinates; change of Cartesian co-ordinates; distance between two points; coordinates of the mid-point of a segment; geometric locus, its equation; equation of a straight line: general form; equation of a plane curve: circle, parabola, ellipse, hyperbola).

Trigonometry (definition of arc and angle; measurement of an angle; units; circular functions of an angle; classical elementary formulas; the trigonometric functions, sine and cosine, triangles).

Statistics *Learning objectives:* To provide the participants with the necessary knowledge of the statistical tools that will be used in other subjects.

Syllabus: Purpose and scope of statistics; introduction to probability, accuracy; tabulation and graphical representation of statistical data; measures of central tendency, dispersion and skewness; introduction to frequency distribution e.g. normal, log-normal, Gumbel, Pearson III; goodness of fit tests; use of probability paper; simple and multiple linear regression; correlation.

Electrical principles for measuring techniques *Learning objectives:* To introduce participants to the basic concepts of electricity that govern some measuring methods and instruments.

Syllabus: Electrical units, principles of magnetism, static electricity, induction of electricity; condensers, current electricity, magnetic action of an electric current, Ohm’s law; practical measurement of different electrical units.

Metrology and sensor technology *Learning objectives:* To provide participants information on the science of measurements and sensor technology.

Syllabus: Physical parameters and their relations and units [SI]. Aspects of: accuracy, resolution, linearity, drift, calibration, re-calibration, correcting, reading and storing frequency, instantaneous/averaged values, summary reporting, archiving,

Table 4.1—Matrix of topical units for the BIPs (contact hours)

Subject	BIP-HTIMT	BIP-HTICT
1. Basic subjects (in hours)		
1.1 Introduction to hydrological processes	6	6
1.2 Mathematics	15	15
1.3 Statistics	20	20
1.4 Electrical principles for measuring techniques	6	6
1.5 Metrology and sensor technology	6	6
1.6 Computer operations	20	30
1.7 Surveying, map reading and photo interpretation	30	10
2. Hydrological subjects (in hours)		
2.1 Meteorology	20	20
2.2 Hydraulics	30	30
2.3 Hydrometry	40	20
2.4 Hydrogeology	40	20
2.5 Water quality	40	20
2.6 Analysis of hydrological data	50	50
2.7 Data storage and retrieval	10	40
2.8 Instruments maintenance	10	40

raw data, processed data, quality control. Measuring principle and installation requirements for bubble gauges, pressure sensors, ultrasonic sensors, turbidity sensors/samplers. GPS, geodetic "total station".

Computer operations *Learning objectives:* To provide participants an introduction to the use of PCs and assist them to use some common software packages.

Syllabus: Introduction to PCs; general principles: in- and output devices (peripherals as floppy disk, tape, printer, plotter); programming principles, flow charts; introduction to a simple programming language; operation systems; instruction on handling PCs; load, start and run programmes; use of programme packages in hydrology in the field of frequency statistics, regression analysis, hydraulics of rivers such as discharge, water slope including cross-section, preparation of year-book tables and graphs; data quality analysis and storage.

Surveying, map reading and photo interpretation *Learning objectives:* To provide the participants with a working knowledge on surveys, maps and photos used in hydrology.

Syllabus: Introduction, objectives and uses of different types of surveys, plans and maps and their hydrologic application; survey organization; measurement of lines and distances in the field; planimetry; barometric elevation; optical parts of geodetic instruments; levelling: instruments and their adjustment, bench marks, field books, booking and reduction of levels, sources of errors, longitudinal and cross sections, profiles, river surveys, contouring; theodolite survey: instruments and measurement of angles, tachometric surveys, processing of survey data; principles of geomorphology, geomorphological characteristics of catchments and their evaluation on maps; principles of photogrammetry, aerial photographs and their interpretation.

Hydrological subjects
Meteorology *Learning objectives:* To provide participants with a basic understanding of meteorological processes and the measurement of the variables relevant to the hydrological cycle.

Syllabus: Definition; composition of the atmosphere; heat balance; measurement of components: radiation, air and soil temperature, humidity, wind; water cycles in the atmosphere: evaporation, cloud formation and cloud measurement, precipitation processes; climatology: basic factors; influence of relief influence of snow and ice; classification of climates; microclimate; network of meteorological stations. Synoptic meteorology and weather forecasts;

Hydraulics *Learning objectives:* To familiarize participants with basic aspects of hydraulics and sediment transport that are necessary in hydrological activities.

Syllabus: Definition and units; hydrostatics: pressure and its measurement, pressure diagrams; open channel hydraulics: steady and unsteady flow, uniform and non-uniform flow, application of Bernoulli's equation, Chezy and Manning formulas, measuring devices: flumes, notches, weirs and orifices; backwater effect and bifurcation effect; flow in pipes; sediment transport and river-bed processes.

Hydrometry *Learning objectives:* Participants should be able, after completing the subject, to cooperate in the selection of sites and techniques and to perform measurements of water levels, discharges and sediment transport under safe conditions.

Syllabus: General introduction and purposes, principles of measurements national and international standards, site selection, design and construction of stations; types of gauges, stage measurement, discharge measurements: velocity distribution, measurement of velocity by current meters and floats, tracer dilution and other techniques of measurement by weirs and flumes, measurement of bed load and suspended load accuracy and sources of errors; frequency of measurement; evaluation of high water marks; operation and maintenance of gauges; stage discharge relationship, their stability and shifting control; extension of rating curves. Safety procedures.

Hydrogeology *Learning objectives:* To familiarize participants with groundwater resources, and to provide them with basic knowledge of related topics.

Syllabus: Basic concepts in geology: the cycle of erosion (tectonic uplift, erosion, transportation, sedimentation); principal rock types and their mineral composition; soils and soil formation: hydraulic properties of rocks and soils; porosity, permeability and Darcy's law; concept of groundwater potential and water level in wells; aquifers and aquitards; confined (artesian) and unconfined condition; hydraulic stratification of the sub-surface; groundwater contours and sub-surface flow; groundwater-surface water relations (gaining and losing streams). Exploration for groundwater supplies; geophysics, test drilling; construction of wells; pump tests, cone of influence, interference; observation wells and draw down measurements; discharge measurements; analysis of test data steady and unsteady conditions – Thiem, Theis and Jacob methods simple computer solutions. Estimating well capacity. Boundary conditions and river connected aquifers. Regional aquifers, overexploitation. Groundwater quality and sources of contamination; contaminant migration in the subsurface. Shallow wells; springs.

Water quality *Learning objectives:* To provide participants with basic knowledge in chemistry related to water quality and to familiarize them with the collection and the analysis of water samples.

Syllabus: Fundamental chemistry; properties of elements and periodic table; compounds, basic chemical reaction; water quality; definitions, theory of solutions and basic principles of electrochemistry; important chemical and physical characteristics, chemical classification of waters, pH value, samples and their preservation; collection for chemical and biological analysis (methods), procedures for analysis of water samples, conductivity, BOD, COD, major and minor dissolved constituents; chemistry of rivers, lakes and groundwater, seas and oceans, eutrophication; water pollution: pesticides, water borne diseases, point and non point sources, precautions.

Analysis of hydrological data *Learning objectives:* To provide participants with the theoretical background on hydrological data analysis and familiarize them with the most common hydrological analysis.

Syllabus: Representativity of hydrologic data in space and time frequency and time of observations, non-recording and recording instruments, data availability, errors and their detection, maps and charts; interpretation of precipitation data (adjustment, interpolation of missing data, spatial distributions, isohyetal maps, areal rainfall, depth area duration analysis, intensity duration curves); evaporation and evapotranspiration; evaporation from free water and soil surfaces, pan coefficient, basin evaporation; infiltration: rates, empirical formula, hydrograph; interpretation of streamflow data: spatial distribution, maps of specific runoff, time distribution of runoff volume, introduction to unit hydrographs, statistical analysis of floods and droughts.

Data storage and retrieval *Learning objectives:* To provide the participants with a working understanding of hydrological data storage and retrieval systems.

Syllabus: Report forms, protocol; transmission of data, quality control: checking of data; general methods of processing: daily and monthly summaries, extremes, duration curves; publication; data banks, data storage and retrieval: yearbooks.

Instruments maintenance *Learning objectives:* To familiarize participants with common practices on instruments maintenance.

Syllabus: Repair and maintenance: workshop technology, electric and electronic practices, safety and security precautions, engineering drawing (working sketches, drawings for spare parts); installation, repair and field tests for instruments, calibration of instruments.

CHAPTER 5

CONTINUING EDUCATION AND TRAINING (CET)

Definitions and objectives of CET

Modes of instruction and learning

Methods, materials and techniques for CET

Training needs analysis and strategies for CET

The relation between jobs and CET

Lifelong learning through continuing education and training (CET) is becoming an integral part of everyone's professional and personal life. Modes, methods and supporting techniques for continuing education and training activities are manifold and their correct choice will enhance the efficiency of the learning process. Lifelong learning is a cultural process, which is realized not only through CET.

However, the learner's motivation is most important and ideally should match the objectives of the employee's organization in a perspective of continuing professional development. This requires a full-fledged strategy for continuing education and training in order to complement, update or increase the job-competency of the personnel. Ultimately this will lead to a true "learning organization" where human resources are optimized.

5.1 DEFINITIONS AND OBJECTIVES OF CET

Continuing education and training is a comprehensive term, defined as non-formal education and training for those who are employed or seeking employment after formal education and training. Methods of CET differ widely and may utilize several modes of delivery. Also, appropriate techniques and tools for CET are important and must be selected according to the target group and the aims of the programme. The need for CET arises from the weakening of a person’s overall knowledge and skills with time due to the “erosion” of knowledge and the time-dependency of skills (Figure 5.1). Continuing education and training is therefore considered as a lifelong learning process.

It is useful to establish several terms and concepts.

Open and distance learning (ODL) comprises an organized set of instructional objectives, content and processes designed to be presented to learners who are separated (in space and/or time) from the instructor or from traditional classrooms. Open and distance learning is a mode of CET. An example of a well-known organization providing ODL is the Open University in the UK. Its methodology has been followed in many countries.

Continuing professional development (CPD) consists of tailor-made CET activities in a specified profession leading to the achievement of competencies needed to perform new tasks. It is directed towards a given job and therefore is mainly organized/requested by the employer: It is essentially demand-driven while CET is often supply-driven. Hence, the issue of CPD is the matching between demand and supply. On the demand side, clear articulation of demand is not always available or the supply may not be known. Likewise, specific training needs may not be well known on the supply side.

Competency based training (CBT) is a new trend for structured, non-formal opportunity training developed for personnel in the workplace. Typically CBT involves:

- a breakdown of tasks in units and elements;
- specific performance requirements and ranges;
- testing and evidence requirements;
- some formal recognition by employer or external bodies.

An example of formal recognition can be found in the National Vocational Qualifications awarded by the Qualifications and Curriculum Authority in the United Kingdom.

Actors in CET are the “learners” or “trainees” and the “teachers” or “trainers”. In CPD learners and teachers may switch their role as appropriate when new knowledge and skills in specific domains are transferred.

Stakeholders is the term to describe CET “providers” (schools, universities, training institutions or departments of companies and agencies, e.g. the Regional Meteorological

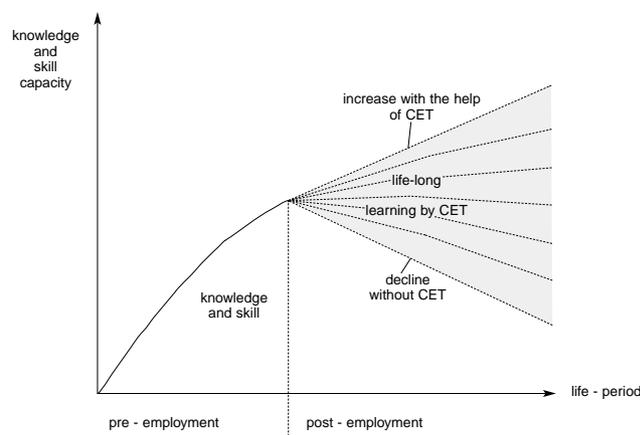


Figure 5.1—The role of CET in maintaining the knowledge and skills of an individual (Van der Beken, 1993)

Training Centres (RMTCs) of WMO) and CET “users” (public agencies and companies with their employees, individuals or citizens and communities or representations thereof) taking part in CET activities and thus forming the “learning society”. In CET, if the learner is seeking a job, the “labour market” may be considered as a stakeholder. In CPD the “employer” of the learner is the major stakeholder.

5.2 MODES OF INSTRUCTION AND LEARNING

The classical mode of instruction is the *ex cathedra* one: the learner is exposed to theoretical knowledge exercised through tutorials and training in the field. Open learning as defined above, may be considered as a special “mode” of instruction with a remote “teacher-learner” relationship which differs substantially from the classical one which is essentially a “person-to-person” relationship.

The *problem-solving approach* brings the real-life problem to be solved directly to the learner and the transfer process of knowledge and skills is made step by step by solving the problem. Both modes have their advantages and disadvantages, but the problem-solving approach is presently gaining more and more attention from educators. It is a learning-by-doing mode, which is very appropriate for CET, CPD and CBT.

The *project-oriented approach* calls for group work by the learners and is especially useful where a holistic approach is required, such as in IWRM. It has the important supplementary advantage that attitude, behaviour, judgement, participation and communication skills, the so-called “soft” skills of the learners, are addressed.

Collaborative learning is a modern version of the project-oriented approach where information and communications technology (ICT) is applied through the internet. It is also called (web-based learning: distance learning using a virtual project-oriented approach) with groups of learners in different places. It allows for interdisciplinary and international team composition. The organizational structure, work plan, work distribution and coordination are obviously very important and difficult issues of collaborative web-based learning.

5.3 METHODS, MATERIALS AND TECHNIQUES FOR CET

Methods for CET may be ranked according to the level of monitoring involved. These methods have advantages and disadvantages, summarized in Table 5.1.

Each method can be supported by one or several materials and techniques. A description of each method follows – ranked roughly according to an increasing level of the technology.

Methods *On-the-job training*

On-the-job training, also called in-house-training, is the most common form of CET since it ranges from a short oral instruction by a supervisor to formal training activities within the enterprise. It varies in intensity and in time demand. Normally, no mobility is involved and the bulk of teaching can be done by the in-house staff of the enterprise.

This method of CET is normally highly monitored and often encompasses a person-to-person relationship. This is especially the case for apprenticeships and coaching. While the former often leads to a recognized qualification and may even encompass a part-time formal education (e.g. evening or weekend education), the latter is more an informal arrangement whereby the trainee works alongside and under the supervision of a mentor. The advantage of coaching is that either the trainee or the tutor does not see it as imposition; it is inexpensive and easily obtained on the job.

On-the-job training is not exclusively a person-to-person activity. Cost-effectiveness may increase if more than one individual is trained at the same time. Therefore, enterprises may appoint trainers in-house or they may hire professional trainers from outside to train in-house people. However, the employer may also wish to send the employee to another enterprise, possibly even abroad, for on-the-job training.

Classroom education Given the limitation of the number of trainees who can undergo a CET programme by apprenticeship, conventional classroom education and training is in many cases more cost-effective. For a given duration, teacher(s) and trainees are brought together and fulfil a CET activity which can be adapted to the needs of the average trainee. Classroom education can range from formal lecturing instruction to open seminar type of contact learning. It may be entirely theoretical or practice oriented. The course may be individually tailored to the immediate needs of the enterprise or it may be a course open to the general public. The duration may vary from an hour to a couple of weeks, part time and full time. In classroom education, group training prevails over individual methods. Classroom education may form only a part of a major programme of training activities, which includes laboratory work, fieldwork etc. (see Section 3.2, BIP-HWR – Integrating activities). Such education may eventually take the combined form of open learning and short courses/workshops/seminars.

Open learning Open learning is well suited to both recurring training and acquiring new knowledge.

It is particularly flexible and can be applied equally to large groups and to individuals. It requires a high degree of initiative from the trainee and is freely chosen or established by the trainee taking into account the supporting techniques available to him/her. Open learning makes use of correspondence courses, radio and television broadcasting and distance learning systems, other self-instructional materials (learning packages, software packages) and internet-based material. Unless the trainee is only interested in the pure self-learning process without any monitoring, open learning will involve some level of monitoring by face-to-face counselling, workshops, roving seminars and by correspondence.

If this form of learning is to be efficient, it should incorporate a high level of structure and organization, involving well-prepared monitoring schemes and advanced learning technologies. In this respect it differs essentially from self-learning which, although utilizing similar supporting techniques, is the most unstructured form of learning.

For cost-effectiveness this means that a large group of trainees must be targeted since the development of appropriate supporting techniques is very costly. This has resulted in limited use of open learning in hydrology.

Workshops, crash courses, seminars Workshops, crash courses, refresher courses, seminars, roving seminars and summer schools are methods, which have the common feature of being of short duration (two or three days up to a few weeks). Their objectives may differ and they may use a wide range of supporting techniques. In general, one could say that these methods are of a more intensive nature than any other form of execution. As a result, the scope of these forms is often narrow or limited to some special topic within a given discipline or area. The varying methods may be described as follows:

Workshop: meeting that offers opportunities for persons with a common interest or problem to meet with specialists to receive first-hand knowledge and to undertake practical work;

Crash course: an organized body of instruction designed to meet urgent requirements in the shortest possible time by an intensive utilization of resources;

Refresher course: activities intended to revise and renew previously learned attitudes, knowledge and skill patterns which have deteriorated through disuse or which need up-dating;

Seminar: a short course or conference making extensive use of participative methods and devoted to the exclusive study of one subject with the object of furthering knowledge in that area;

Roving seminar: the high cost of a seminar can be reduced by organizing roving seminars where the instructors travel from one training site to another and repeat the course; audience and purpose must be similar at each site;

Summer school: this form has been created to make use of leisure time to train generally higher academic staff and instructors for purposes of refreshing, updating and innovative studies.

Special conferences A special conference does not have a typical training objective nor is it involved with the practical instruction of participants; it is a transfer of knowledge and may complement other CET methods. Participants normally cannot interact, as they are passive listeners. The benefit to the participant cannot easily be monitored. Nevertheless, discussions and personal contacts can be considered individual enrichments. Often conferences provide a catalyst and an incentive for further studies regardless of the intensity of personal involvement.

Technical visits Technical visits and study tours are CET activities, which illustrate practical application of the knowledge or skill gathered by other CET methods. Hydrology as an engineering and environmental science is intimately concerned with visual observational activities and therefore field studies form an essential part of general hydrological education (see Section 3.2). Visual impressions have a long-lasting effect on the trainee and often revive interest. Many theoretical findings, perceived by the trainee only in an abstract way, become better understood and integral part of the trainee's understanding.

Self-learning Self-learning must be considered as the lowest degree of organized learning and also involves minimal monitoring. Yet, its value in CET should not be underestimated as it involves the highest degree of personal initiative and commitment. In its widest sense it is close to acquiring knowledge as a hobby and thus enjoys the fullest self-identification of the trainee. But even where self-learning is being undertaken as a complementary or supporting measure in order to improve professional capabilities, the trainee will feel fully committed and may even be prepared to invest personal funds.

Many people feel the necessity to upgrade themselves without waiting for an initiative from the employer. On the contrary, they might consider the employer's initiative a warning that their job is in danger. Hence, it might be concluded that self-learning, along with overall on-the-job instruction, is the most frequent used method of CET.

Self-learning or self-instruction requires self-study materials such as books, learning packages, computer-aided-learning and other advanced learning technologies, so that the learner can progress either without teacher intervention or with a minimum of teacher guidance. The learner is fully independent and can choose his/her own pace of study.

Supporting materials and techniques
Elementary material In its requirements for training materials CET does not differ from any other training activity in schools, enterprises and university. Thus blackboards, paper pads, pencils, calculators etc. are indispensable and are mentioned here only for the sake of completeness.

Textbooks and printed materials Textbook and other printed study material is undoubtedly a principal source of study material for a given course. Their important role is unquestionable and forms the basis of instruction at any level. Self-learning with the use of printed material is an individualistic method, fully depending on the individual study habits and capabilities.

Correspondence courses and self-instructional material Correspondence education is characterized by a systematic exchange between teacher and trainee(s) of learning material sent by mail. It is a typical supporting technique in adult education. Courses designed for this particular form of distance

<i>Methods and materials and techniques of CET</i>	<i>Advantages</i>	<i>Disadvantages</i>
On-the-job training	Very intensive monitoring Flexible Inexpensive No mobility required	Limited in number and extent Difficult to quantitatively measure performance
Classroom education	Cost-effective High number of learners Expected result well defined	Long-term planning needed Does not necessarily respond to individual needs Limited monitoring
Open learning	Freedom of use of time No mobility required Independent of number of trainees Repetitive learning possible Supporting techniques can be selected	No direct contact between trainees and trainer High personal effort required Danger of decreasing motivation Lack of programme coherence is possible
Workshops, crash courses, seminars	Clear objectives Topics abreast with scientific progress Interaction and contacts High learning efficiency Minimum leave of absence	High mobility costs Audience may be too heterogeneous Requires high degree of preparation Qualified lecturers needed
Special conferences	Discussions and personal contacts Incentives	Interaction is limited No monitoring High cost
Technical visits	Long-lasting effect Inspiration Social impact	High cost Intensive didactic preparation is needed Output is difficult to assess
Self-learning	Full commitment Personally tailored Flexible in time and method/tool	Insufficient pace of learning progress Not recognized Some techniques may be too costly
Textbooks	Available for repetition at any time Concentration can be optimised Associative learning Unit step learning according to intellectual capacity	Sometimes too general or too specialized Feedback from author is not possible
Printed material or handouts	First information, more targeted to the group of learners User's manuals	Design and lay-out may be poor
Correspondence courses and self-instructional material	No mobility involved High degree of flexibility Combines the best in print and non-print techniques	Procedure is heavy No personal contacts Only basic subjects available
Audio-visual techniques	Enhancing and reinforcing methods and other materials	Time constraints in the case of radio and television broadcasting
Computer-based techniques (CAL, etc.)	High degree of flexibility Automatic monitoring can be included	Production is expensive Pedagogic aspects not yet well investigated Appropriate hardware and software is needed
Advanced learning technologies and online-learning techniques	Interactive participation is possible through internet No mobility costs Monitoring can be organized for the individual	High production costs Pedagogic aspects not yet well investigated Broad band access to internet is needed for some applications

Table 5.1—Methods and materials and techniques of CET – advantages and disadvantages

learning may consist of the same textbooks/workbooks used in classroom education but the books are generally not suitable and not sufficient. The correspondence courses should be prepared in a “self-instructional” format, including self-tests or self-assessment exercises and with some provision for alternative routes and through selection of the material.

The procedure is that a course sub-set is mailed to the trainee for reading and for replying to questions on solving exercises. The trainee returns his/her assignment to the distant tutor who checks it and replies, eventually with a new sub-set and the procedure re-commences.

Correspondence courses often form an integral part of the multimedia approach and online-learning environments.

Audio-visual and computer-based techniques

Traditional multimedia techniques (audio- and video cassettes, radio and television) enhance the learning process at all levels and can reinforce the value of each method of CET.

Computer-based techniques use computers with software packages and computer-aided-learning (CAL) material, with diskettes, CD-ROMs and digital video disks (DVD). It must be recognized that development of CAL-material, and the like, is expensive and requires expertise on different levels. Once good products are available, CAL and similar material is very useful for many CET methods.

Advanced learning technologies or online-learning techniques

Advanced learning technologies (ALT) and online-learning or e-learning techniques are combinations of technologies or tools based on ICT and allow trainees at the same place or at different places to use software and other resources synchronously or asynchronously and to communicate and interact with the (remote) teacher and with each other. Table 5.2 describes the possibilities.

The web-based collaborating learning mode, as referred to in Section 5.2, is using these possibilities to the fullest, but is still in its experimental phase. It goes without saying that further developments may be expected in the future.

5.4 TRAINING NEEDS ANALYSIS AND STRATEGIES FOR CET

Appropriate CET methods and adequate supporting materials and techniques must be chosen in order to fulfil the objectives of CET and to reach the highest level of efficiency for a given trainee in a given environment. Figure 5.2 illustrates this “parameter harmonization” or alignment of someone’s initial knowledge and skills with parameter 1 objectives of the organization, parameter 2 CET-method chosen and parameter 3 commitment of the individual. As for all human activities, motivation and incentives (or rewards) are essential; for CET the primary incentive is often career advancement.

Another issue of CET is the target group for which a CET programme is implemented. Continuous education and training is expensive and thus the planning,

Table 5.2—Online learning environment – time and space interaction modes (T. Hasan, 2002)

	<i>Same place</i>	<i>Different places</i>
Same time	Synchronous <ul style="list-style-type: none"> • Classroom • In-class workshops, seminars • In-house training 	Distributed synchronous <ul style="list-style-type: none"> • Internet chat • Video-audio conferencing • Interactive television
Different time	Asynchronous <ul style="list-style-type: none"> • Extended library hours • Archives • Digital libraries • Computer laboratories 	Distributed asynchronous <ul style="list-style-type: none"> • E-mail, internet hypertext, newsgroups, distribution lists, etc • Print-based correspondence material

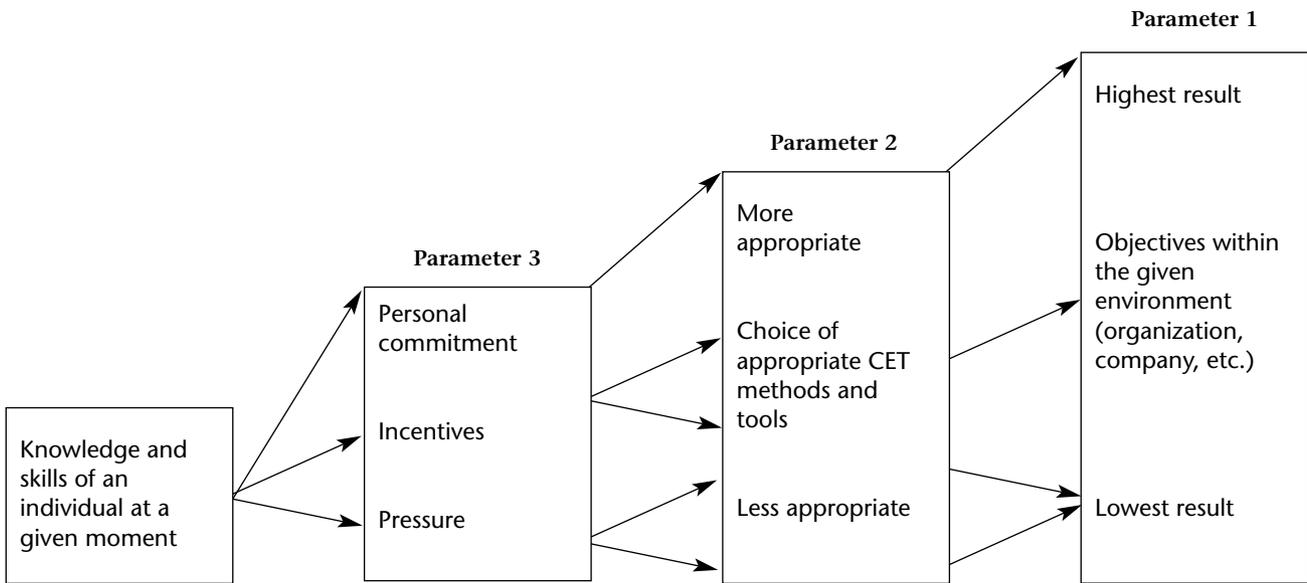


Figure 5.2—The GILBRICH parameter harmonization model: the CPD objectives (parameter 1) of the organization will be best met if the appropriate CET method and tools are selected (parameter 2) and the trainee has a personal commitment (parameter 3).

design, implementation and delivery are often tailored for a group of trainees, not necessarily with the same initial knowledge and skills level. Moreover the method/technique used may not suit all trainees equally well. The incentives may also differ among trainees.

A systematic cycle of identification of needs, definition of objectives, selection of methods and supporting techniques, evaluation and feedback must be applied (Figure 5.3).

Given the qualitative nature of CET activities, managerial concepts like efficiency and effectiveness can be easily confused. Yet, efficiency measures the performance of a process within a system, while effectiveness evaluates what it produces (what is the effect of the process) in relation to its objectives. For instance an education programme may be efficient because its cost/trainee ratio stays within a satisfactory range, but will show a low degree of effectiveness by providing training that is unsuited to the qualifications and skills required by the world of work. It is noted that it is often harder to find measurable indicators for effectiveness than for efficiency. In any event, the two concepts should not be mixed up. Figure 5.4 illustrates this distinction.

In CET, as well as in formal education and training, one can measure the increase of knowledge and skills of the participants before and after the CET delivery, typically by examinations. The overall efficiency of the training includes this measure, but is also based on the selection of the participants, the CET planning and design, contents and delivery. This efficiency of training does not necessarily include a full cost-benefit analysis, although CET providers would of course intend to cover costs.

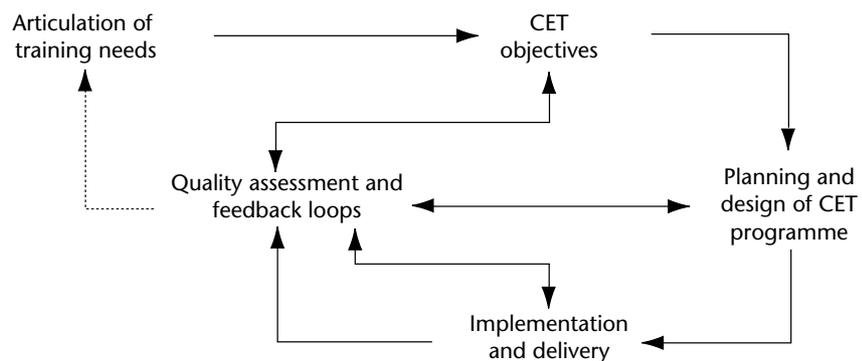
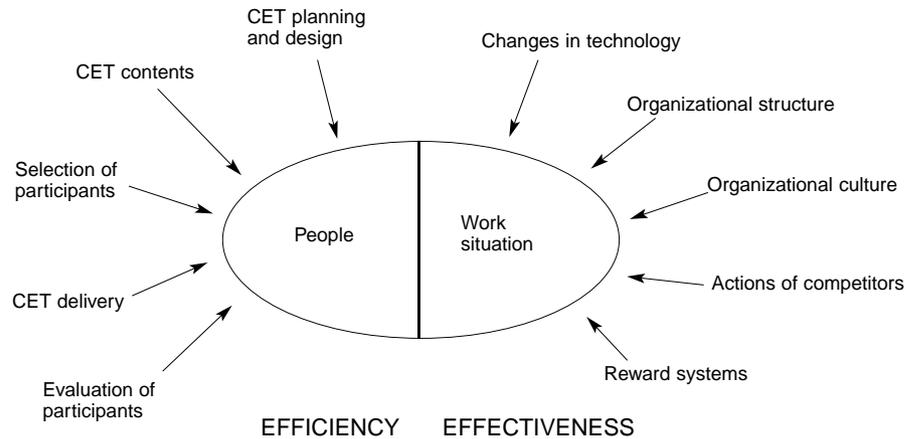


Figure 5.3—The systematic cycle for CET

Figure 5.4—Framework for making distinction between the efficiency and effectiveness of a CET programme.



Effectiveness or impact, however, is more directed towards the individual's competency to perform well in a given work situation. Organizational structure and culture, actions of competitors, reward system, personal fulfilment, etc. will play a role and therefore the "impact" of a CET programme is not really measurable. The loss encountered by not enhancing the necessary competency of personnel is difficult, if not impossible to quantify.

Thus the correct articulation of training needs, the careful selection of trainees, the targeted recruitment of trainers, the choice of the best CET-programme, i.e. the matching of demand and supply, the cost-benefit relation and ultimately the appropriate work-environment where the newly acquired knowledge, skills and competencies of the trainee will be put into practice, are of great importance and must be considered in any CET-policy. A step towards addressing these issues is the implementation of quality assurance and assessment in any CET-programme (see Appendix 1). In some cases, e.g. in UK, "professional" accreditation applies to CET and CPD.

5.5 THE RELATION BETWEEN JOBS AND CET

Job descriptions

Jobs (i.e. positions or posts in a given organization or company) in IWRM require competencies related to the responsibilities outline in Table 2.2 (Chapter 2).

If the job is well defined and the related job-competencies are clearly described, a heuristic back-casting should ideally lead to identification of the knowledge and skills to be acquired in the specific curricula appropriate for a given job.

In reality, given the multitude of jobs in any given profession, and particularly in the field of IWRM, it is not economically feasible to implement and deliver formal education and training programmes for all identified jobs. Hence, the rationale for the grouping of hydrological personnel (Hydrologists, Hydrological Technicians, complementary professionals) for whom Basic Instruction Packages (BIP-HWR, BIP-HTIM, BIP-HTICT and BIP-DSM, BIP-ENV, BIP-SEL) have been introduced in Chapter 2 (Fig. 2.1).

Thus formal education and training cannot fulfil all job-competency requirements. Rather, formal education and training should develop the right attitude and aptitude in a person to learn further through non-formal education and training (i.e. CET) and through informal learning. The organization employing the learner has the responsibility to facilitate the employee's progress towards the required competency level and should therefore establish and support a continuing professional development (CPD) or a competency-based training (CBT) programme for each employee, tailored to the objectives of the organization. Accordingly, the employer:

- *describes* the job in terms of a general statement on the position/post and hierarchical relationships, main objectives, key tasks, expected outcome, competency requirements;

- *defines* the category of personnel who could best fill in the post, i.e. Hydrologist, Hydrological Technician or complementary professional;
- *issues* the appropriate vacancy announcement;
- *selects* the candidate with the most appropriate qualification for the category of personnel defined;
- *establishes* a CPD or CBT programme, in order to complement, update or increase the job-competency of the employee, through CET.

A prototype example of a job description for a regional manager is given for information in Appendix 2 (adapted from Bruen, 1993 pp. 56–59).

CET Programming and Human Resources Policy

Many water sector organizations are currently undergoing major technical changes, due to well-known factors such as rapid ICT changes; modernization and diversification of observation systems, particularly remote sensing; important advances in earth sciences and in computational methods and techniques. As already noted in Chapter 1, these organizations are also changing their traditional mission and management styles, in order to be able to cope with the new demands from the public and private sectors within the context of accelerating liberalization and globalization of products and services. In fact, strategies, organizational structure and management, working methods and procedures, performance criteria, organizational culture and institutional image, as well as human resources (HR) policies and systems are being re-thought in order to align with new organizational objectives.

Since the human dimension is fundamental in any organizational change, people must understand the changes, be willing to adapt and be able to implement the changes. New working methods and procedures have to be assimilated by the staff within relatively short time frames. They must: acquire new skills; absorb more information; perform new tasks; improve their knowledge and performance; modify their attitudes as to how things should be done; and adapt their value judgement and behaviour. A shift in the attitude of the staff towards CPD, including self-development, becomes essential, in order to fully achieve the desired transformation. Appropriately, the HR department will have to:

- contribute to the definition of the organization's strategy and to advise on the short and long-term staff needs in each branch of activity;
- elaborate an HR Master Plan consistent with the organization's evolving mission, its new context and objectives; the plan should include realistic implementation scenarios and describe jobs as shown in Appendix 2;
- compare defined job competencies with actual job performances;
- articulate precisely the training demand and match it with available CET opportunities;
- prepare an adequate range of training options, specifically suited for the target personnel in terms of branch specificity, motivation and incentives, as well as programme contents, duration, delivery method, evaluation and certification in close cooperation with the departments and trainers;
- organize training delivery in a timely manner;
- select trainees in consultation with the departments.

Additionally, it becomes necessary to harmonize the envisaged organizational changes with staff available for their implementation. These changes may involve alterations in competencies required of staff, including career paths as administrator/managers, often the end destination of professionals.

Therefore, the main challenge for the HR department is to be able rapidly to transform itself in order to build a truly integrated system that encompasses several functions: human resources planning and staff re-deployment and staff training and retraining. The actual implementation of these functions must be sustainable and yet in accordance with continuing changing needs. Only then will the HR policy be able to ensure that the concerned learning organization has the required staff numbers at the right time, with the right competencies.

PART B

EXAMPLES

Examples of Basic Instruction Packages

Examples of job-competency requirements in the main branches of activity

It is hard enough that we cannot learn for the whole of our life. Our ancestors managed to live on the education they got when they were young. But today, we must all relearn at least every fifth year for not getting out of date”.

(Johann Wolfgang Goethe in Die Wahlverwandschaften I, 4; 1809)

While Part A provided generic guidance for personnel classification, main disciplines, mandatory instruction and continuing professional development of hydrological personnel, Part B offers some real-life examples which may inspire instructors (and managers) in defining their own requirements for hydrological personnel adapted to local circumstances and specific purposes. It is not the intention of this publication to provide an inventory of either existing instruction packages or instructional books and materials.

The alluded examples are written down in two separate chapters. Chapter 6 deals with Basic Instruction Packages for the initial qualification of Hydrologists and Hydrological Technicians. Chapter 7 illustrates job-competency requirements for some of the most common IWRM-jobs. The examples were kindly provided by the following experts: P. Chola (Zambia), C. Farias (Venezuela), D. Rabuffetti and S. Barbero (Italy), I. Shiklomanov (Russian Federation) and B. Stewart (Australia).

CHAPTER 6

EXAMPLES OF INSTRUCTION PACKAGES

Examples of Basic Instruction Packages for hydrological professionals

Examples of Basic Instruction Packages for Hydrological Technicians

Following on from Chapter 3, which provided a framework for Basic Instruction Packages for Hydrologists and complementary professionals, this Chapter presents selected examples from Belgium, The Netherlands, Australia and the United Kingdom of programmes for BIP-HWR, BIP-DSM, BIP-ENV and BIP-SEL. In addition, building on the BIPs for Hydrological Technicians in two branches of specialization given in Chapter 4, examples are presented of a short course run several times in Africa and long-term on-the-job training from Canada.

- 6.1 **EXAMPLES OF BASIC INSTRUCTION PACKAGES FOR HYDROLOGICAL PROFESSIONALS** The following examples of BIPs have been selected to illustrate the wide range of postgraduate degree programmes that might prepare a person for a career in integrated water resources management. The information is not intended to be correct in all details at the time of publication of this Guideline; readers wishing to obtain the latest information may do so via the web addresses provided in the text.

Example of a BIP-HWR The Free University Brussels and the Catholic University Leuven in Belgium jointly offer a two-year Master of Science programme in Water Resources Engineering, referred to by the acronym IUPWARE (Inter-University Programme in Water Resources Engineering). The programme consists of a first year of complementary studies, followed by a second year in which the core topics are supplemented by a choice of one out of four elective streams, each involving a further two topics. One of these electives is entitled Hydrology. Although the structure of the programme including the Hydrology elective differs in structure from the BIP-HWR summarized in Chapter 3, the contents of the respective curricula are substantially the same. BIP-HWR is presented in an earth systems science framework, whereas the IUPWARE Hydrology option emphasizes engineering applications. This example has therefore been chosen specifically to illustrate the point that the content of a programme matching BIP-HWR may be found within several different academic frameworks, each of which may place particular weight upon a different type of professional activity.

The detailed syllabi for the individual courses may be found in the relevant course documentation (visit <http://www.iupware.be>), which is regularly updated with respect to changes in structure and syllabi. The outline provided below contains only an indicative summary of course content. The relative weight of each course is expressed in terms of credit points using the European Credit Transfer System (ECTS) notation. In this system, the total workload associated with one hour of lectures per week plus one hour of exercises, workshops or practical classes for a nominal 14-week semester amounts to approximately 2.5 credits.

For completeness, details of the other three options in the IUPWARE programme, covering Irrigation, Water Quality and Aquatic Ecology respectively, are included in the following outline.

IUPWARE syllabus and structure **First year courses (45 ECTS credits, 5 per course)**

- C1 Basic Calculus (bridging course with no credits awarded)
A review of basic mathematical techniques frequently encountered or applied in WRE, including calculus, linear algebra and vectors and scalars
- C2 Mathematical Methods
An introduction to advanced mathematical techniques required for the analysis and solution of problems in fluid mechanics, including partial differential equations and numerical techniques for their solution
- C3 Statistical methods
An introduction to the concepts of probability and statistics for use in hydrology and water management, comprising descriptive statistics; probability theory; probability distributions and parameter estimation; hypothesis testing; frequency analysis; regression and correlation; and an introduction to time-series analysis
- C4 Land Evaluation
Methods for predicting the suitability of land for specific purposes based upon soils and climate, and sustainability issues with respect to irrigated agriculture and soil conservation
- C5 Hydraulics
Techniques for the analysis and design of pipes and pipe networks; open channels and open-channel networks; pumps and pumping stations; and drainage canals
- C6 Surface Hydrology
Basic knowledge of the hydrological cycle and hydrological processes, including the relationship between rainfall and runoff, and the routing of floods
- C7 Groundwater Hydrology
Principles and properties of groundwater occurrence and dynamics, and techniques for groundwater exploration, exploitation and management

- C8 Irrigation Agronomy
An introduction to agro-climatology, soil-water-plant relationships, the estimation of irrigation water requirements and crop scheduling principles
- C9 Aquatic Ecology
An introduction to the structure and functions of freshwater and marine ecosystems, including water quality assessment and the management and rehabilitation of natural aquatic environments
- C10 Water Quality and Treatment
An introduction to water quality assessment, including physical, chemical, biological and microbiological characteristics, and methods for water and waste-water treatment

Workshops (15 ECTS credits, 3 per workshop)

- W1 Information Technology
An introduction to the use of PC-based networks for problem solving (including spreadsheets), electronic communication, information retrieval, and the reporting and presentation of results
- W2 Hydrometry
An introduction to techniques for the measurement of water level, velocity, flow, pressure, and sediment transport in a variety of field and laboratory situations
- W3 Social, Political and Economic Aspects of Water Engineering
An introduction to social, political and institutional aspects of water resources development projects, illustrated with case studies and the framework provided by international organizations
- W4 Environmental Impact Assessment
An introduction to EIA procedures and regulations, the scoping of projects and proposals for mitigation measures
- W5 Economic Analysis of Water Resources Projects
Economic and financial analyses, cost-benefit analysis, sensitivity analysis and the treatment of uncertainty

Second year courses (50 ECTS credits)

- G1 GIS and remote Sensing in WRE (5 credits)
An introduction to spatial information processing using GIS, remote sensing and image processing
- G2 Advanced Hydraulics (5 credits)
Methodologies for analysis and design using numerical and physical models for problems involving rapidly-varied flow, unsteady flow and sediment transport
- G3 Water Quality Modelling (5 credits)
A treatment of the structure and application of water quality models for rivers, lakes and estuaries
- G4 Systems Approach to Water Management (5 credits)
The application of modern tools of systems analysis to the management and control of water resources and environmental systems
- G5 Management of Water Use and Re-use (3 credits)
Water management in relation to water resources and water quality; water suitability; water conservation and technology; and the re-use of treated waters
- G6 Integrated project Design (5 credits); Seminars (3 credits); Thesis (17 credits)
A team-building exercise; seminars by visiting speakers; and an individual thesis on a topic relating to the home country of the participant

Option 1 Hydrology (10 ECTS credits, 5 per course)

- G7 Surface Water Modelling
A workshop to familiarize participants with a generic tool for rainfall-runoff and sediment transport modelling and routing, and application to the evaluation of management scenarios for a river basin
- G8 Groundwater Modelling
An introduction to the modelling of groundwater flow and the simulation of groundwater pollution, and the application of readily-available models to a case study

Option 2 Irrigation (10 ECTS credits, 5 per course)

- G9 Irrigation Engineering and Technology
The design of irrigation and drainage systems, with particular emphasis on field applications of different types of systems, including case studies
- G10 Planning, Operation and Management of Irrigation Projects
Techniques and procedures for achieving optimal and efficient operation and management of irrigation systems, with practical exercises on rice and multiple crop systems

Option 3 Water Quality (10 ECTS credits, 5 per course)

- G11 Hydraulics of Waste-water Collection and Water Supply
The engineering design of water supply and waste-water collection systems
- G12 Water and Waste-water Treatment
The characteristics, functioning and design of different types of drinking water and waste-water treatment plants, including design exercises and site visits

Option 4 Aquatic Ecology (10 ECTS credits, 5 per course)

- G13 Monitoring of Water Quality
The monitoring of water quality using physical-chemical and biological methods and an introduction to ecotoxicology
- G14 Advanced Aquatic Ecology
Concepts in aquatic ecology, with particular emphasis on tropical and sub-tropical habitats and the design of field and experimental studies for data collection and model-building

Example of a BIP-DSM

In 1991, the International Institute for Infrastructural, Hydraulic and Environmental Engineering (IHE) in Delft, The Netherlands, introduced a post-graduate, post-experience diploma course in Hydroinformatics. In 1997, this programme was recast as a Masters programme requiring 50 credit points (one CP being 40 hours of student effort). The following summary relates to an updated version of the programme, which now places a greater emphasis on ICT and knowledge management (visit <http://www.ihe.nl/hydroinformatics>).

1. Basics (11 credits)

- 1.1 Introduction to Hydroinformatics and the Course
- 1.2 Hydraulics and Fluid Mechanics: *1-, 2- and 3-D flows; mass and momentum conservation; turbulence and friction; modelling packages; transient flows; kinematic and diffusive wave approximations; transport problems; dimensional analysis*
- 1.3 Use of Computers: *computer usage office packages; MATLAB*
- 1.4 Mathematical Techniques: *basic mathematics; statistics; partial differential equations; Fourier analysis and transforms; optimization techniques; functional analysis; modern mathematics*
- 1.5 Natural Environment: *biology and water quality; properties of natural systems; mathematical formulation of chemical and biological processes; primary production and nutrient cycles; heavy metals and micro-pollutants; ecohydraulics*
- 1.6 Mathematical Modelling: *nature and context of modelling; conceptualization; software validation; modelling in the context of projects; model building, calibration and verification; model uncertainty; modelling in practice*

2. Physically-based Modelling (11 credits)

- 1.7 River Systems Modelling: *theory of wave propagation and river storage mechanisms; effect of roughness and geometry; theory of characteristics; exercises on simple networks*
- 1.8 (a) Coastal Modelling and Advanced River Modelling: *coastal, estuarial and harbour systems; river morphology and sediment transport; 2-D modelling of river and coastal hydrodynamics; or*
(b) Urban Water Systems Modelling: *urban water systems; water distribution modelling; waste water and storm water collection modelling; wastewater treatment plants; receiving water impact modelling; sewer rehabilitation*
- 1.9 Groundwater flow and Transport Modelling: *continuum approach; saturated and unsaturated flow modelling; contaminant transport modelling; modelling packages*

- 1.10 Hydrological Processes and Modelling: *hydrological and hydrogeological processes; hydrological modelling; physically-based catchment modelling*
- 1.11 Numerical Methods for Differential Equations: *Finite differences for ordinary differential equations; implicit and explicit schemes; consistency, stability and convergence; multi-dimensional problems; finite elements; finite volumes*
- 1.12 Advanced Numerical Methods and Computational Hydraulics (option): *one-dimensional networks and topological issues; multi-dimensional problems; techniques for discontinuous flows; conservation laws; Riemann solvers; Godunov schemes; multi-dimensional approaches*

3. Information and Communications Technology (ICT) (8 credits)

- 1.13 ICT: *ICT in the water sector; computer internals and peripherals; parallel computing; operating systems; programming environments; operating systems; Windows architecture; local and wide-area networks; internet; internet programming; algorithms; data structures; linear and non-linear search and sort; artificial intelligence; machine learning; soft computing*
- 1.14 Software Engineering: *software development environments; languages; data types; operators and expressions; statements; prototyping; software specification and design; functional and object-orientated design; interface design; software documentation and validation*
- 1.15 Modelling Systems Development: *developing modelling and graphical components of a water-based system using standard numerical and computer graphics toolboxes*
- 1.16 Databases, Information and Knowledge Systems: *information and knowledge; role of internet; hierarchical, network and relational data models; design of information systems and data bases; distributed and client-server data base systems; e-commerce; knowledge management; document management and collaborative systems*
- 1.17 Geographical Information Systems: *spatially-distributed information and map types; coordinate systems and projections; basic operations*
- 1.18 Monitoring Systems: *modern and traditional monitoring devices; data transport, storage and visualization; communications concepts, media and protocols; data validation, labelling and reconstruction; preparation for use in modelling*
- 1.19 Advanced Software Engineering and Database, Information and Knowledge Systems (option): *object-orientated programming; encapsulation, inheritance and polymorphism; object linking and embedding technology; internet technologies; document management and collaborative systems*

4. Data-driven Modelling and Machine Learning (3 credits)

- 1.20 Applied Statistics: *data screening; frequency analysis; regression and correlation; regionalization; introduction to time series analysis; autocorrelation and spectral analysis; ARIMA processes; multivariate and disaggregation processes*
- 1.21 Data-driven Modelling: *data-driven and physically-based models; data mining, machine learning and soft computing; decision and association trees; artificial neural networks Bayesian learning; fuzzy systems; clustering and classification; chaotic time series; competitive ANNs; Kohonen networks*
- 1.22 Evolutionary Algorithms and Intelligent Automata: *search algorithms; evolutionary algorithms; evolutionary programming; intelligent automata; emergent computation*

5. Integration and Management Subjects (8 credits)

- 1.23 Real-time Control: *RTC in urban, rural and regional water systems; model building; control strategies; conceptual framework for control systems; supervisory control and data acquisition systems; control theory; fuzzy controllers; practical implementation of control systems*
- 1.24 Professorial Lectures in Hydroinformatics: *hydroinformatics and numerical modelling; knowledge encapsulation and framing; semiotics and post modernism; symbolic and post-symbolic eras; socio-technical aspects of hydroinformatics; gender and hydroinformatics*
- 1.25 Water Industry in Europe: *historical introduction; systems analysis; legislation; administration; privatization; projects and financing*
- 1.26 Environmental Impact Assessment: *introduction to EIA; tools; scoring methods*

- 1.27 Systems Analysis and Decision Support: *definition and role of system analysis in engineering planning; basic concepts; simulation and optimization models; objective functions and constraints; multi-objectives and trade-offs; uncertainty; stochastic processes; real-time control; decision support systems*
 - 1.28 Collaborative Engineering and Knowledge Management: *organization; structures; communication; documentation; coordination; collaborative tools and application sharing; platform facilities*
 - 1.29 Individual Study
- 6. Other Subjects (9 credits)**
- 1.30 Capita selecta and invited speakers
 - 1.31 Technical writing
 - 1.32 Fieldwork in hydrometry and microbiology
 - 1.33 Fieldtrips

Example of a BIP-ENV The Master of Engineering Science (MEngSc) programmes at the University of New South Wales in Sydney, Australia, are offered in a variety of delivery modes and units of credit. Among these programmes is a specialization in Water Quality Management, the content of which provides a ready example of a BIP-ENV. The 36 units of core credits in this course are offered in three-day short-course mode. The additional 12 credits required may be allocated either to a project or to a combination of other courses. The core courses, which all carry 3 units of credit (one UC is equivalent to seven hours of tuition), are:

1. CVEN7819 Hydrological Processes

Hydrological cycle; atmospheric circulation; weather systems and oceanic circulation; moisture in the atmosphere; measurement of meteorological parameters; calculation of potential evaporation and evapotranspiration.

2. CVEN7807 Groundwater Hydrology

Physical properties of groundwater. Darcy flow; field and laboratory tests. Principles of groundwater flow. Storage and transmissivity. Flow nets; local and regional flow systems – springs; interactions with surface water. Groundwater modelling. Unsaturated zone flow and calculation of infiltration. Groundwater recharge mechanisms and water balance calculations.

3. CVEN7811 Natural and Artificial Wetlands

Catchment and river morphological processes; river response to changed conditions; river engineering and management. Sediment transport for cohesive and non-cohesive materials; computer modelling packages.

4. CVEN7825 Aquatic Chemistry for Engineering

Introduction to principles of the chemistry of natural waters and polluted systems; acidity and alkalinity, mineral precipitation, complexation, oxidation/reduction and surface and colloid chemistry. Tools for solution of water chemistry problems including introduction chemical specialization computer codes.

5. CVEN7826 Microbiology for Engineering

Fundamentals of water and wastewater chemistry; microbiological groups and reactions in various environments; concepts of chemical equilibria, reaction rates, pH, alkalinity, oxidation-reduction and complexation; microbial growth, metabolic diversity and persistence of disease-causing micro-organisms.

6. CVEN7806 Catchment and Water Quality Management

Fundamental concepts; total catchment management; issues in non-urban catchment inclusive of non-point-source contamination and erosion; water quality management in catchments, rivers, lakes, reservoirs, estuaries and the coastal zone

7. CVEN7815 Introduction to Catchment Models

Concepts and reductionist approach to modelling of catchment processes influencing the quantity and quality of surface runoff from a catchment. Different forms of models, catchment modelling systems, and their implementation; sources of information and data required for operation of modelling systems. Calibration, validation, and reliability of catchment modelling systems.

8. CVEN7824 Risk Analysis in Water Engineering

Introduction to the theory of probability; joint, marginal and conditional probability; commonly used probability distributions; expectations and estimation of model parameters; hypothesis testing and confidence limits; uses in water and coastal engineering - applications to flood design, Monte Carlo simulation, bootstrap, and hydrological, human and environmental risk assessment.

9. CVEN7816 Catchment Surface Models

Processes influencing the generation of surface runoff and the transportation of pollutant constituents with surface runoff. Surface runoff models: UH methods, time-area methods, linear and non-linear reservoir models and, kinematic wave methods. Water quality models: UAL, Simple methods, and process based models. Selection of appropriate models.

10. CVEN7805 Coastal Zone Management

Coastal hazards and management options assessment within local, State and Federal government frameworks. Environmental and ecological aspects including climate change and marine biota. Dredging and spoil disposal. Asset management and risk assessment in the coastal zone.

11. CVEN7827 Contaminant Transport in the Environment

Fundamentals of dispersion common to all environmental media (air, water, soil). Dispersion processes: nature of dispersion processes, advection and diffusion. Modelling of dispersion in the atmosphere, water bodies and soil. Transport processes in wetlands, lakes, reservoirs, estuaries, and coastal waters. Data collection relating to transport and dispersion.

12. CVEN7828 Transformation and the Fate of Contaminants

Major variables and general principles of the transformation and fate of pollutants. Air chemistry: interaction and degradation of gaseous pollutants in the atmosphere. Aquatic chemistry: transformation and fate of particles, organic contaminants, nutrients and metals released to coastal waters.

Example of a BIP-SEL

In the year 2000, the Centre for Energy, Petroleum and Mineral Law and Policy (CEPMLP) at the University of Dundee (UK) inaugurated a Master of Business Administration (MBA) degree in Water Law and Policy. This degree requires a total of 24 credits which can be taken in a variety of modes (full time, part time and distance learning). There are three specialized electives (at two credits each) to be taken from CEPMLP and a further nine management courses with the same credit rating to be obtained from a core MBA programme. The three specialized electives are summarized as follows (see <http://www.dundee.ac.uk/cepmlp>):

1. International Law of Water Resources

Basic concepts of international law relating to the navigational and non-navigational uses of international water resources; water use in the context of international law: notions of sovereignty; substantive and procedural rules governing international water use and allocation; the role of international commissions; dispute resolution and preventative diplomacy. The work of the International Law Commission of the UN, the International Law Association and the Institute of International Law.

2. National Water Law and Regulation

Historical and current concepts of water law; existing systems of water law: civil law countries, common law countries and Muslim countries; issues of ownership and entitle-

ment; legal regimes governing the right to use water; regulation of beneficial use of water resources and water quality and pollution; water resources administration and privatization of the water industry.

3. Economics of Natural Resources

Economic concepts for analysing natural resources issues; background to the study of natural resources; decision-making over time; property rights; welfare and the role of government; non-renewable resource use: theory of depletion; renewable resource use: management of stocks; externalities and pollution; pollution policy in practice; government regulation and policy in natural resources.

6.2 EXAMPLES OF BASIC INSTRUCTIONAL PACKAGES FOR HYDROLOGICAL TECHNICIANS

Example of short course for Hydrological Technicians

In this section one example of a Hydrological Technicians course, which was run several times in Africa and another example on-the-job training from Canada, are presented.

UNESCO's International Hydrological Programme (IHP) has published lecture notes for the short course on Applied Hydrology for Technicians (Balek *et al.*, 1994) which was run several times in Africa over a three-month period. The basic target groups were senior technicians in developing countries, particularly in semi-arid and humid tropical zones. Table 6.1 is extracted from this publication. A course organizer, using this example, could update the contents along the lines presented in Chapter 4 and supplement suitable materials for the prevailing local climatic conditions or for particular hydrological situations. Of course, demonstrations and fieldwork should complement the classroom education and training.

Example of long-term training

The following example is extracted from a training programme for Hydrology Technicians of Environment Canada, which was extensively documented and described by T. Winkler (1994). Teachers' lecture notes were also collected, published and regularly revised.

The Canadian programme is essentially a long-term programme for in-house or on-the-job training: about 90 days of training over four and a half years. This is equivalent to about 4.5 to 5 months of training given over the five-day working week. Of this, about 80 per cent of the training is done indoors and 20 per cent in the field. It must be stressed that the long-term programme allows for ongoing practice and guidance ("coaching") over the entire period of training. The training programme allows also for seasonality for example.

Over the five-year period, training is organized as shown in Table 6.2. The year indicated is the year in which training is initiated, the numbers refer to the lesson packages. A training schedule is used to plan instruction and to monitor progress (Fig. 6.1). It allows both the supervisor and the technician to know when training is expected of them and to manage time accordingly. The schedule is particularly important for training that is given over a long period of time because it is possible to forget what has been completed and what remains to be done.

The information presented in Table 6.2 and Figure 6.1 was updated by Environment Canada in 2002.

Volume 1	Chapter 1	Introduction to hydrology	Volume 3	Chapter 6	Hydrogeology
	1.1	Definitions		6.1	Introduction
	1.2	The hydrological cycle		6.2	Basic geology
	1.3	Related disciplines		6.3	Soils and soil water
	1.4	The techniques of hydrology		6.4	Groundwater occurrence
	1.5	The problems of applied hydrology		6.5	Geological formations as aquifers
	1.6	Starting points and time scales		6.6	Groundwater movement
	1.7	Individual floods and storms		6.7	Pumping test analysis
	1.8	Classification of catchments by their ecology		6.8	Groundwater exploration
	1.9	When there is no data		6.9	Groundwater extraction
	1.10	Contaminant hydrology			
1.11	The hydrologist in integrated development				
	Chapter 2	Water and environment		Chapter 7	Water quality
	2.1	Environment and the concept of sustainability		7.1	Introduction
	2.2	The ecosystem approach		7.2	Basic chemical definitions
	2.3	Environmental effects of water resources development		7.3	Physical characteristics
	2.4	Environmental Impact Assessment (EIA)		7.4	Water quality parameters
	2.5	Environmentally sound management of inland water – EMINWA		7.5	Chemical classification of waters
				7.6	Sampling and preservation
				7.7	Basic water analysis
				7.8	Water quality standards
	Chapter 3	Basic subjects		Chapter 8	Water resources development
	3.1	Units of measurement		8.1	River basin concept
	3.2	Basic mathematics		8.2	Water resources assessment
	3.3	Statistics		8.3	Design floods
	3.4	Surveying		8.4	Utilization of water resources by man
	3.5	Map reading and air photos		8.5	Water supply and sanitation
				8.6	Saline water intrusion
Volume 2	Chapter 4	Meteorology and hydrometeorology	Volume 4	Chapter 9	Hydrological analysis
	4.1	Introduction		9.1	Data storage and retrieval
	4.2	Air circulation in tropical regions		9.2	Elementary analysis of hydrological data
	4.3	Meteorological observation sites			
	4.4	Precipitation		9.3	Floods and droughts
	4.5	Air temperature			
	4.6	Atmospheric humidity			
	4.7	Wind			
	4.8	Sunshine and radiation			
	4.9	Atmospheric pressure			
	4.10	Evapotranspiration and evaporation			
4.11	Automatic weather stations				
	Chapter 5	Hydrometry		Chapter 10	Introduction to microcomputers
	5.1	Basic hydraulics		10.1	Introduction
	5.2	Open-channel flow		10.2	Microcomputer hardware
	5.3	Discharge rating		10.3	Computer software
	5.4	Primary data processing		10.4	Introduction to basic programming
	5.5	Sediment transport		10.5	Installation and care of computer equipment
				10.6	Introduction to the use of spreadsheets
				10.7	Applications of microcomputers in data
				10.8	Microcomputers in operational hydrology
				10.9	Microcomputers in remote sensing

Table 6.1—Condensed table of contents of the short course “Applied Hydrology for Technicians” (Balek et al., 1994)

Year	Lesson	Title	Year	Lesson	Title	
1	0	Overview	2	6	Defensive driving/skid school	
	1	Types of gauging stations		25	Wildlife awareness and safety	
	4	Measurement of stage (manual gauges)		3	Introduction to field health and safety	
	5	Measurement of stage (float sensors)			Fast water survival and rescue	
	5.1	Graphic water level (WL) recorder			Ergonomics	
	5.2	Electronic data acquisition system (EDAS): stage measurement			Measurement of stage (servo-manometer)	
	7	Levelling instruments and procedures			Supplying data to users	
	8	Gauge height computations			Bench marks and gauge datum	
	10.1	Discharge measurements (principles)			13	Station description (field and office)
	10.2	Discharge measurements (current meters)			15	Logistics (field trips)
	10.3	Discharge measurements by wading		20	Computation of daily discharge (ice conditions)	
	10.4	Discharge measurements from cableways		22	Station analysis form	
	10.5	Discharge measurements from bridges		27	Suspended-sediment sampling	
	10.6	Discharge measurements from boats		31	Suspended sediment transport (computation)	
	10.7	Discharge measurements from ice cover				
	11	Cable safety	3	2	Site selection	
	14	Vehicle operations		16	Climatological records	
	18	Stage-discharge relation		21	Annual records	
	19	Computation of daily discharge (open water)		12	Gauging station management	
	26	Fluvial sedimentation (introduction)		33	Water quality (site selection)	
32	Computation software systems	4	9	Reservoir contents (computations)		
40	Basic electricity and electronics		17	International gauging stations		
	First aid and cardio pulmonary resuscitation (CPR)		24	Submitting data to headquarters		
	Transportation of dangerous goods		28	Bed material sampling		
	Small craft and water safety		30	Laboratory analysis of sediment		
	Small craft operator		34.1	Water quality measurements – in situ		
	Winter survival		34.2	Water quality measurements – sample collection		
	Workplace hazardous material information system (WHMIS)	5	23	Historical data review		
				Water quality computations, records, modelling		

Table 6.2—Curriculum of a training programme for Hydrology Technicians (Environment Canada, 2002)

Participant _____ Date of appointment _____

Lesson package	EG-3			EG-4			EG-5			Summary	Notes
	Months										
	6	12	18	24	30	36	42	48	54		
0 Overview											
1 Types of stations											
2 Site selection											
3 Bench marks											
4 Stage measurement											
5 Overview: stage recording											
5.1 Graphic WL recorder											
5.2 EDAS: stage measurement											
6 Manometers											
7 Levelling											
8 Gauge height computations											
9 Reservoirs											
10.1 Discharge general											
10.2 Current meters											
10.3 Wading											
10.4 Cableways											
10.5 Bridges											
10.6 Boats											
10.7 Ice cover											
11 Cableway safety											
12 Station management											
13 Station description											
14 Vehicles											
15 Logistics											
16 Climatology											
17 International											
18 Stage/discharge relationship											
19 Open water computations											
20 Ice computation											
21 Annual records											
22 Station analysis											
23 Data review											
24 Data to HQ											
25 Data to users											
26 Fluvial sedimentation											
27 Suspended sediment sampling											
28 Bed material sampling											
30 Sediment laboratory analysis											
31 Sediment computations											
32 Computation software systems											
40 Basic electricity and electronics											
First aid and CPR											
Transportation of dangerous goods											
Small craft and water safety											
Small craft operator											
Winter survival											
WHMIS											
Defensive driving/skid school											
Wildlife awareness and safety											
Introduction to field health and safety											
Fast water survival and rescue											
Ergonomics											
Aircraft safety											as required
Confined space entry											as required
Chainsaw safety											as required
Firearms safety											as required
Fall protection											as required
All terrain vehicle, snowmobile, etc., operations											as required

Figure 6.1—Schedule of a training programme for Hydrological Technicians (Environment Canada, 2002)

CHAPTER 7

EXAMPLES OF JOB-COMPETENCY REQUIREMENTS IN THE MAIN BRANCHES OF ACTIVITY

Hydrometeorological station management

Hydrometeorological data collection and processing

Water resources information and systems management

Natural risks monitoring and warning

Water quality assessment

This Chapter illustrates the job-competency and relevant knowledge and skills required of IWRM personnel assigned to the branches of activity identified in Chapter 2. Experts from individual water-related institutions, provided “real-life” examples in response to specific requests from WMO. Except for some general editing, the structure of the original inputs was essentially maintained. Consequently, there are slight differences in the level of detail and a degree of overlapping in the subject coverage of some examples. Appendix 2 provides a prototype example of job description for Regional Manager that was used to brief those contributing examples.

The five examples may inspire educators and managers to identify the requirements of their institutions for specialized knowledge and skills, and then to translate those requirements in terms of training outcomes. The user may have to adapt those examples to local specific priorities. Accordingly, various topics may receive more or less emphasis than suggested here. It could be that some examples might not even apply to a given country.

Obviously, no one individual would be expected to possess all the competencies illustrated throughout this chapter. However, it would be expected that managers and instructors would make every effort to ensure that the expertise needed in their organizations is well covered by appropriately trained personnel as a whole.

7.1 HYDRO-METEOROLOGICAL STATION MANAGEMENT

Example provided by I. Shiklomanov (Russian Federation).

Job Description

POSITION	Senior Hydrological Engineer hydrometeorological station
ANSWERS TO	Head of hydrometeorological station
IN CHARGE OF	5–15 or more Hydrological Engineers and Technicians
FUNCTIONS/ COMMUNICATIONS	Organizing, managing and participating in hydrological work, within the station's field of activity (river, lake, marsh, water balance) and communicating with interested organizations (water management, transport, hydroenergy, ecology, etc.)
MAIN OBJECTIVES	<ul style="list-style-type: none"> • To organize and participate in work monitoring observers' activities at hydrological posts (training, inspection, on-site verification of observing equipment); • To organize work to develop and monitor observing equipment using computer technology and compile hydrological yearbooks, hydrometeorological event reviews and bulletins on the state of bodies of water, etc.; • To organize the optimization of the hydrological network (closing, transferring and opening hydrological posts).
TRAINING	Higher education, usually a hydrology major from a hydrometeorological institute or a university graduate of hydrology or physical geography.

Main duties and expected results (Senior Engineer Hydrologist)

Main duties	Expected results
Organize and carry out the verification of primary observation data, from the network of hydrological posts serving the station.	Verified books of field observations on the elements of the hydrological regime of bodies of water.
Monitor components using computer spreadsheet technology for the hydrological yearbooks for elements of the hydrological regime: levels, water output (measured and calculated), river turbidity, alluvium flow and its granulometric composition, ice events and temperature regime, etc.	Hydrological yearbooks, containing data on the measured elements of the hydrological regime of bodies of water.
Organize and monitor the recording of measurement data on technical carriers.	Observation and hydrological yearbook data, introduced into technical carriers.
Organize further education seminars for Hydrological Engineers and Technicians on the study of hydrological processes and the application of computer technology for data processing and monitoring, etc.	Practical exercises with Hydrological Engineers and Technicians, furthering their education.
Compile bulletins on the condition of bodies of water for the main stages of the hydrological regime (high-water, flood, low-water) and for different intervals (depending on requirements).	Bulletins on the state of bodies of water for the main stages of the hydrological regime (high-water, flood, low-water) and for different intervals (depending on requirements).
Process and systematize observation data for a multi-year period using computer technology.	Reference books containing data on the measured elements of the hydrological regime of bodies of water, summarized for the multi-year period.

Competency requirements for a Senior Engineer Hydrologist for a hydrometeorological station

- Understanding of the main laws governing the formation of the area's hydrological regime, basic hydrology, hydraulics, hydrography, geomorphology, meteorology and climatology;
- Knowledge of the main organizational principles of the hydrological, hydrochemical and meteorological observing networks; familiarity with the instruments, equipment (installation and progress monitoring) and the methods for taking measurements and processing observation data; ability to monitor the quality of observing equipment in field conditions and at the hydrometeorological station; familiarity with the computer technology for processing hydrometeorological information; capacity to monitor the preparation of databases on technical carriers and their transfer to the State archive of hydrometeorological information in the Russian Federation;
- Ability to prepare the publications "Yearly data on surface water regimes and resources", "Observing equipment", "Multi-year data on surface water regimes and resources " and "Meteorological monthly", etc. when summarizing data for the multi-year period the relationship is to be established between the elements of the hydrological regime and the main determining factors: precipitation, soil, plant cover, etc. and various graphs confirming these relationships are produced;
- Knowledge of the basic probability theory and the statistical analyses of the several-year variations of hydrological and meteorological characteristics in time and space and ability to monitor the quality of observing equipment (completeness and reliability of observations) using computer programs;
- Ability to analyse the representative nature of hydrometeorological posts and meteorological stations by:
 - In field conditions, checking completeness and reliability of flow calculations (particularly in water meadows) and assessing meteorological station shading following the construction of residential and industrial buildings etc.;
 - In laboratory conditions, carrying out hydrological and statistical analyses of observations in order to ascertain any systematic and random error of measurement;
- Knowledge of the methods for measuring and monitoring measured water flows at the different phases of the hydrological regime and in the presence of river-bed deformation, enlarged rivers etc., including:
 - Measuring current speed using both detailed (5 and more vertical points) and basic (2 vertical points) methods;
 - Processing the measurements, producing the table "Measured water flow" and constructing the curves $Q = f(H)$, $w = f(H)$, $V = f(H)$ in order to calculate daily water flow;
- Familiarity with the methods for measuring suspended sediment and bed-load discharge; ability to monitor the application of methods for taking water and bed-load samples to determine the granulometric composition and process these samples in a laboratory to determine granulometric composition and water turbidity; ability to monitor the equipment used to calculate the suspended alluvium and compile the "alluvium flow" tables;
- Familiarity with the methods for:
 - Measuring water and air temperature, determining ice thickness and describing the ice regime for bodies of water;
 - Determining the depth of snow cover at a meteorological station in and in the area around a hydrological post;
 - Determining water reserves in the snow cover and the latter's level of pollution;
- Ability to carry out control datum settings for diagrams at a hydrometeorological post and station elevation referencing to the geodetic network using a level or theodolite;
- Ability to prepare "Contour" and update the "Geographical Characteristics" report;
- Knowledge of the principles for studying the hydrochemical regime of surface water and its level of pollution;

- Knowledge of the migration mechanism of pollutants in the environment and ability to analyse station data on the pollution of bodies of water in order to bring out the impact of pollution;
- Ability to organize and carry out exchanges of observation data and hydrological reference books with interested organizations (water management, transport, hydroenergy, ecology and agriculture, etc.);
- Ability to work in a team of specialists and workers in the different fields of environmental protection.

7.2 HYDRO-METEOROLOGICAL DATA COLLECTION AND PROCESSING

Example provided by C. Farías (Venezuela).

Job Description	Under general supervision to carry out work of mean level of difficulty in operation and maintenance of hydrometeorological stations and/or compute and interpret data collected in the stations. Supervise the work of auxiliary personnel.
Typical tasks	<ul style="list-style-type: none"> • Assess, compute and correct graphics obtained from instruments used in hydrometeorology; • Revise and compute hydrometeorological data and stream gauging in medium size rivers; • Operate topographical instruments; • To prepare inventories of equipment, instruments and graphical material; • To analyse samples of sediment to determine the concentration and the size distribution of fluvial sediments; • To compute the daily discharge in spillways and other hydraulic structures; • To save in magnetic media data obtained from the primary processing of hydrometeorological records.
Minimum requirements	<p>Education and experience:</p> <ul style="list-style-type: none"> • Complete high school, plus first level of the course on hydrometeorology of the Central University (120 hours), plus three years of experience in hydrometeorological work; • Two years working as hydrometeorological auxiliary personnel plus the above-mentioned course.
Knowledge and skills required	<ul style="list-style-type: none"> • Good knowledge of techniques used in hydrometeorology; • Good knowledge of the instruments used in hydrology and meteorology; • Ability to supervise personnel; • Knowledge of arithmetic computations; • Swimming; • Driving vehicles; • Using topographical instruments.

7.3 WATER RESOURCES INFORMATION AND SYSTEMS MANAGEMENT

Example provided by B. Stewart (Australia).

Position, programme and supervisor	<ul style="list-style-type: none"> • Principal Project Officer (Water Resource Information and Systems Management) • Integrated Water Resources Management • Director, Water Monitoring and Information
Purpose of the position	The position provides a head of discipline and leadership for technical matters relating to all aspects of water monitoring (quantity and quality) throughout the

nation. The position is responsible for the provision of appropriate training, information and advice as required to support regional staff, the setting and maintain of standards for water monitoring and the provision of expert advice to senior management on policy and guidelines in relation to hydrometric data collection in response to evolving needs.

Organizational environment

The department's mission is to support economic growth through the sustainable use, development and management of land, water and native vegetation resources, whilst protecting the rights and interests of both the individual and the community.

The department's vision is sustainable land, water and native vegetation with the providing quality products and services to build a prosperous nation.

The responsibilities of the department focus on land services, natural resource management, water resource development, business services and integrated information.

The department is committed to having a strong regional presence building close links with clients.

The Natural Resource Management Programme is one of the business elements of the department. The Programme has principal responsibilities relating to the monitoring, assessment, integrated management and protection of land, water and forest resources.

The charter of the Programme arises from the growing awareness of the finite availability, fragility, extent of degradation and rate of alienation of the natural resource base on which agricultural and forest productivity, as well as urban and rural communities depend. The purpose is to ensure the use, development, and management of the nation's land, water, and forest resources is socially, economically and environmentally sustainable.

Effective service delivery to clients is achieved through coordinated regional management of sub-programmes in each of the five regions. The general managers and regional staff liaise and collaborate closely to ensure effective strategy and policy development and operational service delivery within the following framework:

The general managers are responsible for nationwide resource management policy, sub-programme outcomes and management and service delivery policies, strategies and quality assurance. The regions are responsible for the operational delivery of sub-programmes in accordance with approved policies, priorities, strategies and standards.

Factors such as increased water demands, the sustainable use and management of forests, land resource degradation, the spread of pest plants and animals, heightened community awareness and concern for environmental values and the effects of micro-economic reform on the water industry have resulted in a complex array of competing interests. Consequently, Government and community expectations with respect to the management of natural resources have increased considerably over a short period of time. Addressing the resulting major policy demands requires consultation with stakeholders with differing perspectives. These factors make the development of policy in this field a complex and politically sensitive process.

Primary duties and responsibilities

Lead and coordinate the development/review and implementation of policies, standards, guidelines and performance indicators for hydrometric data collection across the nation and establish appropriate reporting arrangements.

Develop evaluation strategies and guidelines for regularly evaluating the attainment of standards in the implementation of water monitoring activities across the nation.

Advise the Director, Water Monitoring and Information, on matters of policy, standards and operations on a regular basis.

Provide detailed input to the preparation of the nationwide budget for the upgrading, review and ongoing operation and maintenance of the hydrometric networks, in consultation with district staff. Regularly monitor and provide expert advice on expenditure on water monitoring activities.

Liaise with other programmes of the department on all aspects of hydrometric data collection.

Periodically review and develop water monitoring programmes as required and arrange for the implementation of these programmes.

Identify needs for changes to standards, procedures techniques in water monitoring and lead the development of those changes.

Develop and maintain appropriate management and reporting systems.

Develop and maintain relevant internal and external networks.

Provide technical input and expertise in the development and implementation of service level agreements between resource management and other programmes as well as with private clients and regularly monitor the execution of their agreements.

In liaison with regional staff, develop work practices and guidelines for all major aspects of water monitoring activity.

Design, develop and implement training strategies to ensure the maintenance of technical standards and up-to-date knowledge of data collection technology.

Ensure the elements of quality assurance, safety and staff career paths are advanced and maintained.

Oversee the purchase and distribution of hydrometric equipment throughout the nation and undertake forward planning of equipment and monitoring requirements.

Maintain professional currency with new developments in the field of water monitoring liaison with other agency hydrometric personnel and introduction of new technology where appropriate.

Primary delegations and accountabilities

- Financial – as per departmental financial delegations;
- Personnel – as per departmental human resources management delegations.

Selection criteria

- 1 Proven leadership and project management skills together with an expert knowledge of all aspects of water monitoring.
- 2 Well developed conceptual, analytical investigative and evaluative skills with proven ability to develop and implement standards and procedures and prepare complex reports for clients, senior staff and regional staff.
- 3 Proven record of achievement in undertaking water monitoring activities and in providing authoritative expert advice to clients, senior staff and regional staff on water monitoring.

- 4 Well developed interpersonal, networking, presentation and negotiation skills together with the ability to professionally represent the department at appropriate forums.
- 5 Demonstrated ability to develop training material and develop and conduct training events together with a knowledge of, and demonstrated commitment to, the principles and practices of employment equity, ethical conduct and workplace health and safety.

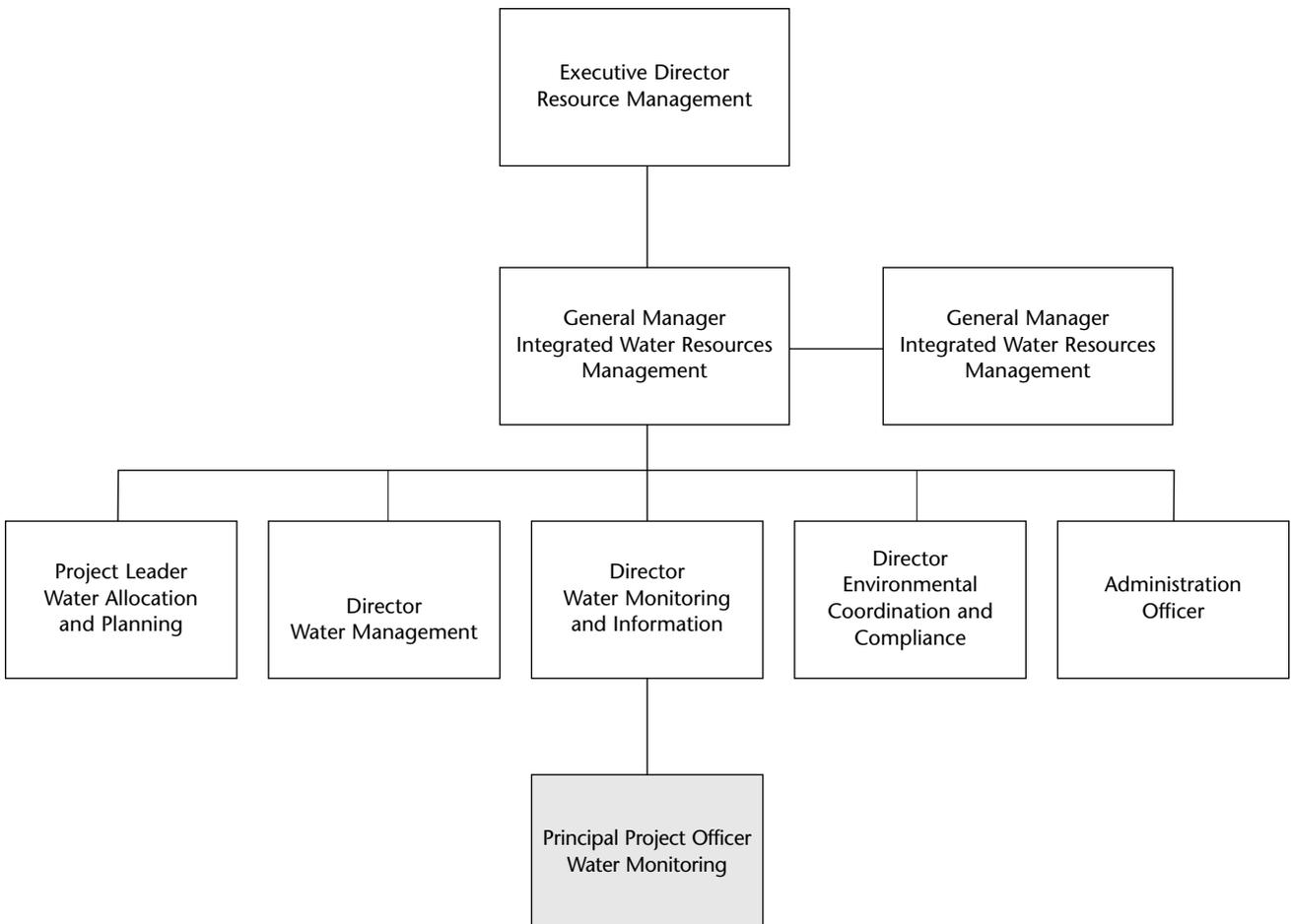
Other information The department is an equal opportunity employer.

To apply for the position it is recommended that you submit:

- A completed “Application for Advertised Position” form;
- One original and three copies of a statement describing how you meet the selection criteria. However should you be unable to supply more than one copy this will not adversely affect your application.

Applications for this position should be marked “Private and Confidential”.

**Natural Resource Management
CENTRAL OFFICE
WATER RESOURCE ALLOCATION AND MANAGEMENT**



7.4 NATURAL RISKS MONITORING AND WARNING

Example provided by D. Rabuffetti and S. Barbero (Italy).

Overview of position

Position:	Technician
Location:	Natural Risks Monitoring Office
Responsible to:	Technical supervisor, Regional unit managers
Directly supervising:	n/a
Function/Relationship with:	Other technician of the staff
Primary objectives:	To watch on real-time measurement coming to the office through the regional surveying network (gauges, meteorological radar). To ensure that at all times the computer network of the meteohydrological unit is working properly.
Category of personnel:	Hydrological Technician
Educational level:	Five year in technical school

Key tasks and expected results	Key tasks	Expected results
	To distribute hydro-meteorological forecasts and alert/alarm bulletins	All the defined authorities (National and Regional Department for Civil Protection, prefectures, etc.) are informed about the possible occurrence of critical events caused by heavy rainfalls and floods.
	To verify that at all times the hydro-meteorological observation network is operating properly	Regional unit managers are informed about problems on gauges or in the radio repeaters for data transmission, watch that the programmed maintenance is performed.
	To follow-up the hydro-meteorological situation	Regional unit managers are informed about the evolution of the hydro-meteorological situation with respect to thresholds fixed by hydrologists, 365 days per year and 24 hours per day during critical events, so that extraordinary bulletins can be emitted as needed.
	To validate and archive data	The meteorological database is always updated following the quality standards decided by the hydrologists.
	To extract data	Specific data and products are prepared exporting data archived in the database as requested by internal or external clients.

Competency requirements	<ul style="list-style-type: none"> • Good knowledge on informatics, computer network management, system administration; • General principles on data transmission, processing and archiving; • Hydrometeorological station and instrumentation functioning; • Basic knowledge on hydrology and meteorology; • Understanding of images obtained from METEO-SAT, meteorological radar and survey network; • Comprehension of output plots of hydrological model; • Data reporting using graphics, data processing from archive and GIS.
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7.5 WATER QUALITY ASSESSMENT

Example provided by P. Chola (Zambia).

Overview of position

Job title:	Water Quality Officer
Ministry:	Ministry of Energy and Water Development
Department:	Department of Water Affairs
Section:	Water Resources Management
Unit:	Water Quality Management
Job purpose:	To undertake compilation and analysis of water quality data in order to facilitate effective assessment of the resource.

Key tasks and expected results	Key result areas	Principal accountabilities (main duties)
	Data compilation and Data analysis	Undertakes timely compilation of water quality data in order to facilitate analysis. Undertakes timely data analysis.
	Production of reports	Undertakes timely production of technical reports on the status of water quality in the country
	Coordination	Undertakes routine coordination on the operations of the provincial laboratories in order to facilitate their effective operations.
	Technical Services	Provides timely technical services on water quality in order to facilitate decision making.
	Management	Manages effectively the national laboratory in order to ensure effective operations.
Reporting relationships	Reports to: Senior Water Quality Officer Other Jobs: Reporting above: Nil Number and level of subordinates: Laboratory Technician (TS/4) Contacts: Regular contact with staff in all units to collect and disseminate data to facilitate effective execution of water quality programmes. Regular contact with stakeholders when collecting data	
Responsibilities	<i>Safety and health of others:</i> Ensure enforcement of safety rules and regulations pertaining to water quality assessments. <i>Responsibility for government resources:</i> Materials used for water quality assessment. <i>Level of authority and decision making:</i> Controls daily operations of the laboratory. <i>Consequence of error:</i> Would result in poor compilation of data leading to inadequate assessment of the status of water resources. <i>Communication skills:</i> Written skills: Ability to prepare, analyse and submit very well written comprehensive and consolidated technical reports. Oral skills: Able to articulate and express himself/herself clearly in the official language	
Knowledge and skills requirements	<i>Minimum primary/secondary education:</i> 5 'O' levels or equivalent. <i>Minimum vocational/professional qualifications:</i> Bachelors degree in chemistry, biochemistry, environmental engineering, or equivalent. Higher National Diploma, Laboratory Technology, two years experience. <i>Minimum relevant pre-job experience:</i> Bachelors degree and Diploma holder with two years working experience.	

Physical skills: Be able to undertake relevant water quality tests and operate relevant equipment.

Other skills/attributes: Good analytical skills; computer literacy.

Environmental and other features

Condition of work place: Office, laboratory and field

Physical effort applied when performing the job: Moderate effort required when analysing and collecting samples

Mental effort applied when performing the job: Substantial mental effort required as the Water Quality Officer will have to compile and analyse data.

Hazards involved in the performance of job: Possibility of an accident while in the laboratory and field.

APPENDICES

Quality assurance and assessment

Example job description – Regional Manager

Glossary of terms

References and annotated bibliography

QUALITY ASSURANCE AND ASSESSMENT

The following discussion of quality assurance and assessment procedures is adapted from Van den Berghe (2000; pp. 165–170) with additional reference to the Accreditation Board for Engineering and Technology (ABET).

WHAT IS QUALITY?

Quality is a multi-dimensional, relative concept and is not new in education and training. Institutions, Teachers, administrators and policy makers have always been concerned with quality. However, the notion of quality has often been ill-defined, if at all. The different viewpoints from which quality in education and training are considered can be summarized as follows:

- Quality from a didactic and/or pedagogical point of view, from which quality is seen as the optimization of the teaching and learning process.
- Quality from a (macro)-economic point of view, involving quality seen as the optimization of education and training costs.
- Quality from a social or sociological point of view in which quality is seen as the optimization of the response to social demand for education and training.
- Quality from a user point of view in which quality is seen as the optimization of demand.
- Quality from a management point of view, i.e. quality seen as the optimization of the organization and processes of education and training.

The definition of quality assurance according to ISO 8402 is:

“All the planned and systematic activities implemented within the quality system, and demonstrated as needed, to provide adequate confidence that an entity will fulfil requirements for quality”.

In practice, in order to be able to implement quality assurance, the following need to be in place:

- Defined quality standards;
- Suitable and available procedures;
- Conformance monitoring of procedures;
- Analysis of causes of non-conformance;
- Eradication of problems through appropriate corrective action.

Therefore the application of quality assurance principles requires consensus on consideration of the main quality attributes. The latter are not always straightforward in education and training – programmes, primarily because not only the “product”, i.e. the course material, but also the “learning process” is of importance.

Quality should be assessed on a regular basis. The baseline for quality in education and training is its effect or impact after a certain period of time. More simply:

Quality in education and training is measured by its impact six months later.

In reality, however, such measurements are very difficult and costly to undertake and are therefore seldom applied either by the provider or by the user. The most frequently used quality measurement is the degree of satisfaction of the learners at the end of the education or training course.

QUALITY ASSESSMENT PROCEDURES

An alternative to such quality measurements is a process of regular self-assessment by both the education and training provider and the education and training user. In the self-assessment process, an organization must first define a number of quality standards and desirable input processes and output characteristics for the education and training programme. An assessment is then made of the extent to which these quality standards and characteristics have been achieved.

Self-assessment may serve a double purpose:

- Through regular self-assessment, an organization will gradually come to understand better the effects and impact of education and training delivered, and therefore come closer to a measurement yardstick of quality in education and training;
- A good self-assessment process will yield many ideas and suggestions for quality improvement, which further contribute to the development of a dynamic educational, training and learning environment.

These insights will in themselves support the development of a “learning organization”, i.e. an organization that has the intrinsic capacity to learn and develop as a whole rather than as a set of individuals.

In addition to self-assessment, one may consider external assessment, i.e. a quality assessment of education and training by an independent “third party”, such as a public body or a certification/accreditation organization. Another type of assessment can be envisaged in which the users are asked to assess the education and training received. These various types of quality assessment procedures have their advantages and disadvantages, as summarized in Table A.1.

From a quality-management perspective, self-assessment is the preferred option. Indeed, assessment by externals and users tend to focus on input- and output-characteristics of training, while the real source of improvement lies in the internal processes. These can only be measured adequately through self-assessment. Moreover, any form of external or user-based assessment may lead to a defensive, rather than a constructive, reaction of the people being assessed. Quality improvement requires a positive motivation towards improvement, which is more easily supported by self-reflection than by external evaluation. Ultimately, self-assessment is the most economical way of assessing quality as an effective mechanism for quality improvement, and is particularly effective when coupled with external review and critique of the self-assessment.

In summary, self-assessment applies to both partners in education and training: the providers and the users. Self-assessment with both parties is important for

- Achieving quality improvement;
- Becoming a learning organization;
- Moving towards a learning society.

Table A.1—Comparison of quality assessment procedures

Type of assessment	Advantages	Disadvantages
Self-assessment	<ul style="list-style-type: none"> - relatively inexpensive - covers the totality of the organization - may involve everyone 	<ul style="list-style-type: none"> - may not be credible - may lack rigor and reliability - may interfere with other activities
User-based assessment	<ul style="list-style-type: none"> - meets real interest of users - inexpensive - real impact can be measured 	<ul style="list-style-type: none"> - only output characteristics - high variability of satisfaction of individual users - users may not understand their own needs
External assessment	<ul style="list-style-type: none"> - high credibility - neutral view and original perspective - comparability and benchmarking 	<ul style="list-style-type: none"> - very expensive - assessors may not be qualified - may interfere with other activities

SAMPLE FRAMEWORK FOR ASSESSMENT AND ACCREDITATION

The ABET EC-2000 (Engineering Criteria-2000) provide a useful example template of topics to be addressed in the self-assessment of an education or training programme. The criteria for the 2002–2003 accreditation cycle as taken from the ABET website are as follows:

It is the responsibility of the institution seeking accreditation of an engineering programme to demonstrate clearly that the programme meets the following criteria.

- Criterion 1. Students** The quality and performance of the students and graduates are important considerations in the evaluation of an engineering programme. The institution must evaluate, advise, and monitor students to determine its success in meeting programme objectives. The institution must have and enforce policies for the acceptance of transfer students and for the validation of courses taken for credit elsewhere. The institution must also have and enforce procedures to assure that all students meet all programme requirements.
- Criterion 2. Programme educational objectives** Each engineering programme for which an institution seeks accreditation or re-accreditation must have in place:
- (a) Detailed published educational objectives that are consistent with the mission of the institution and these criteria;
 - (b) A process based on the needs of the programme's various constituencies in which the objectives are determined and periodically evaluated;
 - (c) A curriculum and processes that ensure the achievement of these objectives;
 - (d) A system of ongoing evaluation that demonstrates achievement of these objectives and uses the results to improve the effectiveness of the programme.
- Criterion 3. Programme outcomes and assessment** Engineering programmes must demonstrate that their graduates have:
- (a) An ability to apply knowledge of mathematics, science, and engineering;
 - (b) An ability to design and conduct experiments, as well as to analyse and interpret data;
 - (c) An ability to design a system, component, or process to meet desired needs;
 - (d) An ability to function on multi-disciplinary teams;
 - (e) An ability to identify, formulate, and solve engineering problems;
 - (f) An understanding of professional and ethical responsibility;
 - (g) An ability to communicate effectively;
 - (h) The broad education necessary to understand the impact of engineering solutions in a global and societal context;
 - (i) A recognition of the need for, and an ability to engage in life-long learning;
 - (j) A knowledge of contemporary issues;
 - (k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
- Each programme must have an assessment process with documented results. Evidence must be given that the results are applied to the further development and improvement of the programme. The assessment process must demonstrate that the outcomes important to the mission of the institution and the objectives of the programme, including those listed above, are being measured. Evidence that may be used includes, but is not limited to the following: student portfolios, including design projects; nationally-normed subject content examinations; alumni surveys that document professional accomplishments and career development activities; employer surveys; and placement data of graduates.
- Criterion 4. Professional component** The professional component requirements specify subject areas appropriate to engineering but do not prescribe specific courses. The engineering faculty must assure that the programme curriculum devotes adequate attention and time to each component, consistent with the objectives of the programme and institu-

tion. Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints that include most of the following considerations: economic; environmental; sustainability; manufacturability; ethical; health and safety; social; and political. The professional component must include: (a) one year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline; (b) one and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study; (c) a general education component that complements the technical content of the curriculum and is consistent with the programme and institution objectives.

- Criterion 5. Faculty The faculty is the heart of any educational programme. The faculty must be of sufficient number; and must have the competencies to cover all of the curricular areas of the programme. There must be sufficient faculty to accommodate adequate levels of student-faculty interaction, student advising and counselling, university service activities, professional development, and interactions with industrial and professional practitioners, as well as employers of students. The programme faculty must have appropriate qualifications and must have and demonstrate sufficient authority to ensure the proper guidance of the programme and to develop and implement processes for the evaluation, assessment, and continuing improvement of the programme, its educational objectives and outcomes. The overall competence of the faculty may be judged by such factors as education, diversity of backgrounds, engineering experience, teaching experience, ability to communicate, enthusiasm for developing more effective programmes, level of scholarship, participation in professional societies and registration as Professional Engineers.
- Criterion 6. Facilities Classrooms, laboratories and associated equipment must be adequate to accomplish the programme objectives and provide an atmosphere conducive to learning. Appropriate facilities must be available to foster faculty-student interaction and to create a climate that encourages professional development and professional activities. Programmes must provide opportunities for students to learn the use of modern engineering tools. Computing and information infrastructures must be in place to support the scholarly activities of the students and faculty and the educational objectives of the 2002–2003 Criteria for Accrediting Engineering Programmes.
- Criterion 7. Institutional support and financial resources Institutional support, financial resources, and constructive leadership must be adequate to assure the quality and continuity of the engineering programme. Resources must be sufficient to attract, retain, and provide for the continued professional development of a well-qualified faculty. Resources also must be sufficient to acquire, maintain, and operate facilities and equipment appropriate for the engineering programme. In addition, support personnel and institutional services must be adequate to meet programme needs.
- Criterion 8. Programme criteria Each programme must satisfy applicable Programme Criteria (if any). Programme Criteria provide the specificity needed for interpretation of the basic level criteria as applicable to a given discipline. Requirements stipulated in the Programme Criteria are limited to the areas of curricular topics and faculty qualifications. If a programme, by virtue of its title, becomes subject to two or more sets of Programme Criteria, then that programme must satisfy each set of Programme Criteria; however, overlapping requirements need to be satisfied only once.

APPENDIX 2

EXAMPLE JOB DESCRIPTION – REGIONAL MANAGER

The following example is given for information only and is adapted from M. Bruen (1993, pp. 56–59). It contains three main sections: A. Job overview; B. Key tasks and expected results and C. Competency requirements.

JOB OVERVIEW

POSITION	Regional Manager
LOCATION	-
RESPONSIBLE TO	Director, Water Resources Monitoring Unit, Department of Environment
DIRECTLY SUPERVISING	Three Hydrological Technicians and other temporary staff, as assigned
FUNCTION/ RELATIONSHIPS WITH	Water Resources Monitoring Unit. Managers and staff, other units of Department of Environment, Staff of Regional Water Boards and client organizations (water companies, industries, public, etc.)
PRIMARY OBJECTIVES	<p>To ensure that at all times the monitoring team operates in professional manner and meets the expressed quality standards required by its clients;</p> <p>To provide, within the monitoring team's area, information on the national water resource, for archiving on the Water Resources Archive;</p> <p>To provide water resource and related information of appropriate quality to other clients;</p> <p>To minimize the costs to central government of the work of the monitoring team, by maintaining an effective and efficient operation and recovering costs at a level consistent with long term stability.</p>
CATEGORY OF PERSONNEL	<p>Hydrologist; or</p> <p>Complementary Professional in Water Resources, with suitable competencies; or</p> <p>Senior Hydrological Technician, with at least ten years experience in monitoring, and a suitable professional development record.</p>
KEY TASKS AND EXPECTED RESULTS	See section B.
COMPETENCY REQUIREMENTS	See section C.

KEY TASKS AND EXPECTED RESULTS (REGIONAL MANAGER JOB)

Key tasks	Expected results
Verify and archive data	Data archive to specified standards. Annual audit reports completed and verified by 30 June of following year for each site. Information requirements of clients met to their satisfaction.
Maintain office site registers	Location of records clearly documented. Status of sites and data clearly documented.
Market services; carry out specific jobs for clients	Increasing demand for service. Capabilities widely known amongst other organizations. Up to 40% recovery of total Water Resources Monitoring budget. Forward plan of workload. Satisfied clients.
Train and develop staff	Staff developed and performing to their full potential. Individual strengths are matched to job opportunities. Staff to get adequate feedback on their performance and career opportunities. Development of abilities in several fields, both technical and managerial. Orderly annual programme of staff training consistent with operational requirements. Current job descriptions for staff.
Maintain technical and managerial skills	Awareness of latest technology and methods. Technical support to team members. Introduction of innovative technology. Efficient and effective management. Clients receive best possible service.
Encourage quality commitment	Completion of all work on time and to standards specified by the client.
Formulate annual and quarterly programmes	Annual programme which includes work for Department of Environment. Knowledge of resources required carrying out programme and resources available for non-programmed work. Quarterly programme and objectives which are achievable but challenging.
Lead and administer survey team operations	Completion of weekly, quarterly and annual programmes on time and to the standard required by clients. Efficient and effective utilization of all resources and staff members. Staff fully extended. Clear communication and harmonious staff relations. Installations and projects operating efficiently. Expenditure within budget.
Obtain resources	Annual budgets sufficient to carry out programmed and non-programmed work. Adequate and suitable equipment and resources to enable staff to meet objectives. Staff available to meet objectives.
Install, maintain and operate equipment	All installations and projects operating efficiently. Records complete, up to date, and according to standards at all times.
Review and maintain work systems	Effective and efficient operation of team and individual staff. Objectives met on time and within budget. Clients receive satisfactory service. Staff involvement in suggesting and implementing improvements.

COMPETENCY
REQUIREMENTS
(REGIONAL MANAGER
JOB)

- Understanding basic principles of hydrology and meteorology.
- Monitoring systems, recording and data transmission. General principles of data management and data information systems for water management. Data processing: entry and editing, validation, correction, completion, transformation, compilation and analysis; functional requirements for database management and processing systems.
- Reporting: presentation of data using graphics; reports. The use of database information systems: stand alone and in relation to simulation models and GIS. Data exchange between models, geographical information systems, spreadsheets and databases.
- Knowledge of quality assurance of data sets, frequency analysis and regionalization of hydrological time series. Measurements of all

hydrometeorological variables. Keeping, checking and adjustments of records.

- Selection of measuring sites and techniques. Selection of types of gauges and recorders; design of the stilling well and accuracy of water level measurement. Bet levels: position fixing including GPS and the use of rangefinder and sextant; sounding of cross-sections including the use of sounding of instruments.
- Discharge measurements: special attention for the most important methods: the current meter methods including the ADCP, the dilution method, the stage-discharge method and the acoustic method.
- Sediment transport: methods and instruments to measure bed load, suspended load and wash load; bottom sampling.
- Flow measuring structures: selection of type; head-discharge.
- Clear appreciation of the importance of collecting hydrological data in a systematic and cost-effective manner and methods for designing a network of hydrological observations.
- Understanding principles of water quality and ecological quality. Field measurements and sampling for river water quality. Groundwater sampling and measurement. Understanding prevention and protection against groundwater pollution.
- Understanding of the institutional, socio-economic and legal context within which water resources planning and management is executed. Knowledge of principles of Environmental Impact Assessment.
- Ability to interact with multidisciplinary teams.

APPENDIX 3

GLOSSARY OF TERMS

<i>Accreditation</i>	The recognition of an educational or training institution as maintaining standards that qualify the graduates for admission to higher or more specialized institutions or for professional practice.
<i>Accreditation Board for Engineering and Technology (ABET)</i>	The non-governmental organization, based in Baltimore, Maryland, USA, that accredits engineering and technology programmes in the United States and, upon request, outside the United States.
<i>Applied hydrology</i>	Branch of hydrology that refers to its application to fields connected with water resources development and management.
<i>Assessment</i>	Evaluation of any aspect of an academic programme (input, output, students, etc) in the context of established criteria.
<i>Basic Instruction Package (BIP)</i>	A framework curriculum recommended for the initial professional formation of personnel to be employed in hydrology and water resources activities. Consistent with the new WMO classification of personnel, there are two different BIPs - one qualifying job-entry level graduate Hydrologists (BIP-H), and another qualifying job-entry-level Hydrological Technicians (BIP-HT).
<i>Certification</i>	Documentation attesting the attendance and successful completion of formal or non-formal education and training activities. In contrast to degrees and diplomas, certificates are not usually recognized as professional qualifications.
<i>Competency</i>	Knowledge and skills required to fulfil correctly a given job. Competency involves also many personal characteristics such as attitude, aptitude, behaviour, ethical perception, judgment, opinion, etc.
<i>Competency Based Training (CBT)</i>	Structured, non-formal opportunity training for personnel predominantly in the workplace.
<i>Complementary professionals in water resources</i>	Professionals working in the field of integrated water resources management (IWRM) in relation to data systems management, ecosystems management and socio-economic and legal aspects.
<i>Continuing Education and Training (CET)</i>	Any formal or non-formal education and/or training activity conceived for recipients who possess already an accredited vocational, professional or academic qualification in the respective or related field.
<i>Continuing Professional Development (CPD)</i>	Continuing education and training (CET) activities in a specified profession leading to the achievement of competencies needed to perform new tasks.
<i>Course unit</i>	Grouping of topical units for organizational purposes
<i>Credit Point</i>	A measure of student effort in formal and non-formal instruction.
<i>Curriculum</i>	The totality of an organized learning experience of a distinct professional profile. It provides the conceptual structure and sets the time frame to acquire a recognizable degree and describes its overall content – e.g. the curriculum of a five-year degree programme in civil engineering at a particular higher education institution: The curriculum is the student's choice from the programme offered by the university. A course is the totality of an organized learning experience in a specific area, e.g. a course on fluid dynamics within the civil engineering curriculum.

<i>Data Systems Management (DSM)</i>	Acquisition, processing, dissemination and archiving of data information, including hardware and software acquisition and maintenance.
<i>EC-2000</i>	The outcomes-based accreditation criteria adopted by ABET's Engineering Accreditation Commission.
<i>Ecosystem</i>	A discrete unit that consists of living and non-living parts, interacting to form a stable system. Fundamental concepts include the flow of energy via the food chain and food webs and the cycling of nutrients biogeochemically. (3rd draft 3rd edition Glossary of Hydrology UNESCO/WMO)
<i>Education</i>	Learning process associated with the transfer of knowledge to an individual.
<i>Engineering hydrology</i>	Branch of applied hydrology that deals with hydrological information intended for engineering applications, e.g. planning, designing, operating and maintaining engineering measures and structures or water works.
<i>Environmental Management (ENV)</i>	Management of environmental quality at watershed and river basin scales, including Environmental Impact Assessment.
<i>European Credit Transfer System (ECTS)</i>	The harmonized system of course credit point allocation used in universities of the European Union.
<i>Facies</i>	The character of a rock formation as displayed by its composition, texture, fossil content, etc.; a formation or body presenting a unified set of properties.
<i>Formal education</i>	Regular school and university education which is carried out, or accredited, by private or public institutions. Formal education relies on classroom training, tutorials and examinations, following a fixed curriculum.
<i>Fluviology</i>	The branch of science that deals with rivers.
<i>Hydraulics</i>	Branch of fluid mechanics dealing with the flow of water (or other liquids) in conduits and open channels (UNESCO/WMO, 1992).
<i>Hydrological Technician (HT)</i>	A person who, following the compulsory education (minimum 9 years of schooling) has completed formal hydrological training consistent with the requirements set forth in the Basic Instruction Package for Hydrological Technicians.
<i>Hydrologist (H)</i>	A person with specialized education, who uses engineering concepts and techniques to observe and forecast the water cycle – from the time when the water is precipitated on the continents till the time it returns to the oceans. This specialized education would be a bachelor's degree in civil engineering, physical sciences, geophysics, agricultural engineering, forestry, etc., usually followed by the completion of a formal postgraduate one-year course in hydrology, consistent with the requirements set forth in the Basic Instruction Package for Hydrologists.
<i>Hydrology</i>	Science that deals with the waters above and below the land surfaces of the Earth, their occurrence, circulation and distribution, both in time and space, their biological, chemical and physical properties, their reaction with their environment, including their relation to living beings. (UNESCO/WMO 1992).
<i>Hydrology and Water Resources (HWR)</i>	Planning, monitoring, forecasting, design, construction, maintenance and management of facilities and systems for productive use of water.
<i>Information and Communications Technology (ICT)</i>	Application of information and communications technologies in the broad field of integrated water resources management.

<i>Instrumentation and Measurement Technology (IMT)</i>	Measurements, operation, and maintenance of instruments for acquisition of water-system data, including data processing and transmission.
<i>Integrated Water Resources Management (IWRM)</i>	Broad paradigm of the (new) philosophy of water resources management calling for a holistic approach. IWRM is a process which aims to ensure the coordinated development and management of water, land and related resources to optimize economic and social welfare without compromising the sustainability of environmental systems. In the broadest sense IWRM means the simultaneous considerations of water quantity and quality aspects of both surface and groundwater resources embedded into a systems analytical approach with reference to other sectoral activities such as industries, aquaculture, agriculture, public health, environmental protection, etc. IWRM needs inter- and multidisciplinary approaches and public participation, public awareness raising etc. There is an obvious education and training need to ‘produce the experts who will be able to implement IWRM in practice.
<i>Knowledge</i>	The ability to understanding and critical, rational and strategic thinking. It allows the individual to adapt more easily to a changing environment.
<i>Lifelong learning</i>	A concept acknowledging the increasing pace of knowledge renewal and additional skills to be acquired, thus necessitating one’s professional life become a continuous process of formal education, continuing education and training (CET), continuing professional development (CPD) and competency based training (CBT).
<i>Metrology</i>	Branch of science that deals with measurement.
<i>Non-formal education</i>	Education that relies on on-the-job-training, coaching, mentoring, in-house activities , etc.
<i>Outcomes</i>	Attributes (capabilities) of students completing an educational or training experience.
<i>Quality Assurance</i>	System for ensuring quality of output involving evaluation, analysis and action to make required changes. Related terms are Quality Assessment, Quality Control and Total Quality Management (TQM).
<i>Self Study</i>	Detailed documentation, analysis and assessment of an educational or training programme, performed by personnel internal to the programme.
<i>Skills</i>	The ability in mental/physical performance of routine tasks. Skills are essential for an individual to operate efficiently in a given society.
<i>Socio-economics and Law (SEL)</i>	Legal, economic and institutional framework for water legislation, allocation, pricing, conflict resolution, etc.
<i>Stakeholder</i>	The general term to describe education and training “providers” (schools, universities, training centres) and “users” (public agencies, interest groups, companies, individuals, water consumers and communities or representatives) taking part in education and training activities and thus forming the learning society. The term applies equally to Integrated Water Resources Management and related participatory processes.
<i>Subject</i>	A subdivision of a topical unit.
<i>Training</i>	Formal and non-formal learning process being associated with the transfer of abilities and skills to an individual. Any action leading to increasing one’s skills.
<i>Topical unit</i>	Grouping of topics of a given discipline.
<i>Water Resources</i>	Water available, and capable of being made available, for use in sufficient quantity and quality at a location and over a period of time appropriate for an identifiable demand (UNESCO/WMO, 1992).

APPENDIX 4

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