Guide to the Implementation of Education and Training Standards in Meteorology and Hydrology

Volume II – Hydrology

(WMO-No. 1083)

FOREWORD (this section will be written once the reviews are completed)

1. INTRODUCTION

The goal of the WMO Basic Instruction Package for Hydrologists (BIP-H) and the Basic Instruction Package for Hydrological Technicians (BIP-HT) is to define standard training programs for entry-level hydrologists and hydrological technicians. BIPs provide the underlying knowledge and skills common to all hydrologists and hydrological technicians that they can build upon to develop the necessary competencies for specific roles and responsibilities. In addition, BIP-H and BIP-HT as outlined could support defining an entry-level hydrologist and a hydrological technician in the *Technical Regulations* (WMO-No. 49).

The fourth edition of the *Guidelines for the Education and Training of Personnel in Meteorology and Operational Hydrology* (WMO-No. 258) was published in 2003.The current edition of BIP-H and HT moved from associated syllabuses to a system based on learning outcomes. Therefore, this update focuses on the essence of what all hydrologists and hydrological technicians shall be able to do into a set of overarching and educational outcomes while making it explicit that the role of the more detailed outcomes is to guide rather than to restrict institutions.

1.1 BIPs in Context

Science and Technology and hydrological service provision have evolved since the publication of the previous edition of these guidelines, requiring an update of the basic education and training for hydrologists and hydrological technicians. Some of the major changes include, closer integration of hydrology and meteorology, increasing use of satellite based data in hydrology, advances in hydrological modeling, increased capacity for flash flood modeling, development of regional and global forecasting systems, adapting probabilistic hydrology, a shift towards user focused service delivery, impact based forecasting, digital transformation using AI, GIS platform and API based dissemination among other advancements. Hence, competency frameworks on these knowledge and skills are being developed, such as the flash-flood forecaster competency framework. In addition, WMO Congress 19 approved amendments to the Manual of the WMO Integrated Processing and Prediction System (WIPPS), including new WIPPS activities: flash floods, sub-seasonal seasonal hydrological predictions, and snow cover predictions. Members can apply to become WIPPS Designated Centers for those activities that will require the development of additional competency frameworks for hydrologists.

Competence is demonstrated through an appropriate combination of knowledge, skills, and behaviour, as defined either in formal competency frameworks or by employers and education or training institutions, including universities. BIP-H and BIP-HT are foundational knowledge and skills for hydrologists and hydrological technicians, but they are insufficient to prepare someone to perform a specific activity such as forecasting and monitoring. Additional and more specialized education or training is required beyond or alongside BIPs to address specific competencies, before someone can work independently with minimal supervision.

It is recognized that there are several pathways to becoming a hydrologist or hydrological technician supported by a wide range of hydrological education and training approaches. Education and Training programmes will often also include complementary topics beyond BIPs, frequently reflecting the priorities and interests of NMHSs, and addressing significant elements required for specific professional roles, as the BIPs contain minimal requirements of education and training.

The key aims of this edition of BIP-H and BIP-HT are:

- To establish foundational knowledge and skills for hydrologists and technicians across all WMO Members
- To place the BIPs within a comprehensive education and training framework, encompassing educational foundations, supporting competency frameworks.
- To ensure BIPs meet the needs of entry-level hydrologists or hydrological technicians who will be working at diverse and evolving operational roles, and to provide guidance on how the BIPs support these roles
- To address the needs of the WMO Members, regardless of size or level of development, by reducing barriers to the education and training of hydrologists and hydrological technicians, who are vital to the delivery of operational hydrological services to key sectors such as disaster risk reduction and water resource management.
- To maintain flexibility so the BIPs can continue meeting future needs in a rapidly evolving world.
- To maintain the intellectual rigour of BIPs so that, while the packages are designed to support entry into operational-related roles, they continue to offer an attractive option for those wanting a grounding in a quantitative physically based, earth-science subject.

- To minimize the work needed to validate or change existing programs while clearly highlighting the necessary changes.
- To support the implementation of competency frameworks by providing a common core of education and training background.

1.2 Main change to this edition

In this edition, the learning outcomes were adopted in the development of BIP-H and BIP-HT. In the learning outcome approach, the emphasis is on the learner achievements rather than on the instructor's intentions or the subjects to be covered as specified in a syllabus. Learning outcomes are what a learner should be able to do after completing a training activity or programme. Learning outcomes have been categorized in three levels of specificity that are interconnected and lie on a continuum: overarching, educational, and Instructional outcomes.

As the BIPs are focused on theoretical and some practical applications, they are developing academic competencies. To perform role-specific activities in the operational environment, the person must be trained in accordance with the requirements defined in the competency frameworks.

A set of overarching learning outcomes has been developed to summarize the demonstrable learning achievements for entry-level hydrologists and hydrological technicians to ensure that BIPs are not misinterpreted as being made up of a series of related but disconnected topics. These overarching outcomes are intended to provide the "glue" that connects the educational and instructional outcomes integrating education and training programs in which interconnections among the various components are made explicit through applying scientific principles to solve real-world problems in an educational and training context.

For hydrological professionals, just two qualifications are recognized: Hydrologists and Hydrological Technicians. The main difference is that Hydrologists are required to hold a university-level degree or equivalent. A hydrological technician generally holds a qualification such as a high-school diploma based on 12 or more years of formal education, specialized formal training in a technical field related to hydrology.

BIP-H has focused on higher-order cognitive processes so that students' and instructors' minds focus on acquiring background knowledge and its applications to real-world problems within the education and training context across various domains and at different spatial and temporal scales. BIP-HT has focused on applied and procedural learning processes so that students' and instructors' attention is directed toward acquiring foundational hydrological knowledge and skills, and their application in structured and supervised education and training contexts.

BIP-H and BIP-HT are flexible enough that institutions and individuals can tailor learning outcomes to their specific national or regional contexts, roles and activities, and achieve these outcomes. The curriculum design section briefly outlines a process that can be used to implement BIPs in a curriculum aligned with the education environment.

1.3 Futureproofing and update of BIPs

BIPs require students to learn applied professional skills in addition to hydrological science to achieve operational competency. BIP-H focuses especially on higher-order cognitive skills rather than specifying declarative knowledge to be covered in a syllabus. BIP-H includes a set of learning outcomes under the topic "Introduction to Hydrological Services." This topic introduces basic hydrological services that can be further developed as part of competence frameworks. In addition, the learning outcomes in the topic provide institutions with guidance on professional skills such as communication skills and information technology, of which students must learn certain aspects to achieve the overarching outcomes. Similarly, BH-HT includes a section on professional learning outcomes on communication and teamwork skills as well as basic computing operations. These actions may provide developing skills on thoughtful judgement and informed decisions that draw on both subject knowledge and critical thinking skills.

A list of the competences for current and future hydrologists and hydrological technicians is also included in the document. These competency frameworks are being developed. Institutions are encouraged to provide opportunities for students to learn about these and other complementary topics such as business and management that will aid their future career progression.

It is important to keep BIPs and associated guidance up to date as science, technology, and practice on hydrological services evolves. Additionally, it is recognized that, despite the meticulous care taken in the preparation of this edition, some errors or omissions might be discovered after publication.

To meet these needs, a review process has been drawn up that will allow WMO Members to propose corrections and amendments and for a more proactive assurance review to be held regularly.

The General Provisions section of the *Technical Regulations* (WMO-No. 49) includes the process to be followed to make changes to standard practices, including BIPs. The process to be carried out is as follows:

– The Capacity Development Division will request and collate on suggestions for amendments from WMO Members.

– Should evidence emerge from the need or desire to amend BIPs, the Capacity Development Division will task an expert team to consider and report on the changes.

– Should no proposals for amendments be received from WMO Members, a regular review will be undertaken by an appointed expert team at eight-year intervals to consider whether BIPs need to be updated.

– If changes are recommended by the expert team, broad consultations will take place on the amended BIPs, and if the changes are supported, they will be put forward for approval by Congress.

The guidance in this volume does not form part of the *Technical Regulations* (WMO-No. 49), but corrections or amendments do need to be approved by the Executive Council. To facilitate the necessary changes to this guidance, the Capacity Development Division will:

– Collate suggestions for corrections or amendments from WMO Members.

– Maintain and publish updates every two years for changes that are minor and non-contentious.

– Conduct a thorough review of the guidance alongside the eight-yearly review of BIPs, as described above.

1.4 Transitioning to this edition

In preparing this edition of BIP-H and BIP-HT, it is considered that institutions may need to undertake additional work to ensure foundational knowledge and skills for hydrologists and hydrological technicians. It is recognized that this may require additional development and effort since the philosophy of integrated and pragmatic learning encapsulated by the overarching learning outcomes and the amended educational outcomes is a new approach to the BIP-H/and HT. However, it is believed that close collaboration among WMO Regional Training Centres to transition the existing training document will reduce the burden on NMHS and provide a more standardized approach to the fundamental concepts in BIP-H/HT.

1.5 Meeting the needs of the WMO hydrological community

The WMO community currently faces an urgent need for more trained hydrologists to meet the growing demands for early warnings related to floods, flash flood, droughts, and other hydrological hazards as well as for integrated water resource management and understanding the impact of climate change in local hydrology. Key priorities include advancing skills and knowledge in data monitoring and management, real-time forecasting, hydrological modelling, and improving the ability to integrate in-situ observations with remote sensing data.

Hydrologists are expected to work closely with meteorologists, disaster managers, and water resources agencies to deliver risk and impact-based early warnings. In addition, stronger capacity is needed in communication, policy support, and climate change adaptation. Overall, the focus has shifted from conducting hydrological analyses to delivering hydrological services for diverse users. NMHSs play a vital role in water security, disaster risk reduction, food security, power generation, navigation among others including supporting climate adaptation and sustainable development.

At present, only a small number of universities offer an undergraduate degree in hydrology. More commonly, hydrology is taught within broader programs such as civil engineering or environmental sciences which are not always designed to meet the needs of NMHSs.

BIP-H and BIP-HT are developed as requirements for the global common core of education background to become a hydrologist or a hydrological technician. However, their implementation is flexible through different education and training institutions if all topics are covered and fully complaint with BIPs. Post-employment training guided by BIPs is intended to fill this gap when employers or others can provide it. This edition of BIPs has been designed to be applied flexibly while overarching and educational outcomes are required for hydrologists and hydrological technician while more specific outcomes are meant to be adapted by the WMO Members and education institutions to fit local needs.

Curriculum design must carefully balance breadth and depth since education and training time are usually limited. An attempt to cover too many topics in detail is costly and most of the time ineffective as much as the material is only briefly addressed and quickly forgotten. The developmental psychologist Howard Gardner stated (Brandt, 1993) that

"*The greatest enemy of understanding is coverage. As long as you are determined to cover everything, you actually ensure that most … are not going to understand.*"

It is the responsibility of the global education and training community to ensure that study programs prepare learners to apply hydrological science in real-world service roles that support people, businesses, and society. This revision aims to encourage more programs that bridge the gap between academic education and practical skills.

1.6. Structure of BIP-H and BIP HT

The overarching learning outcomes have been developed to outline in broad terms, the philosophy of BIP-H and BIP-HT by defining the fundamental knowledge and skills common to all hydrologists and to all hydrological technicians. These outcomes will be achieved through the learning of hydrological science and related topics, using the underpinning background of mathematics, physics, chemistry, geography and geology.

The previous version of BIP-H and BIP-HT was organized with a matrix of topical units and subjects and description of syllabi and included credit points and hours of effort for each topical unit. In the new version of BIP-H and BIP HT, a learning outcome-based approach was adopted. This approach is a significant change from an outline of syllabus, credit points and hours of effort to a system of learning outcomes including overarching, educational and instructional outcomes. This edition of BIP-H and BIP-HT guided by the WMO definition of "Operational Hydrology" as adopted by Cg 18 in Annex 1 to Resolution 24.

"*Operational Hydrology is the real-time and regular measurement, collection, processing, archiving and distribution of hydrological, hydrometeorological and cryospheric data, and the generation of analyses, models, forecasts and warnings which inform water resources management and support water-related decisions, across a spectrum of temporal and spatial scales. Operational hydrology requires capacity building and scientific and technical advancement and innovation in the areas of observation, data standards and services, modelling, prediction, hydro-informatics and decision support, communications, training, and outreach.* "

In the 2003 version, topical units and subjects were grouped under seven headings: supporting science and technology, general hydrology, data collection and processing, hydrological modelling, environment, water resource management, and integrating activities. It also included various branches of hydrology in addition to fundamental hydrological science. The 2003 version of the BIP-H guide included three main topics: pre-requisite, mandatory topics, and specialization for future development.

This version focuses solely on fundamental knowledge and skills. Branches of hydrology identified in the 2003 version were removed in this version since they are mainly areas of specialization and can be attained separately after completing the requirement of BIP-H and BIP-HT in the process of competency implementation. However, a selective list of areas of specialization is included in the document. These were identified by the WMO Members through their Hydrological Advisers based on the survey distributed during this current BIP H/HT development process. Additional areas of specialization will be developed as competencies that will help to build upon BIP-H fundamental knowledge and skills provided in this document.

The hierarchy of education and training is presented in Figure 1.6.1 and 1.6.2. At the top of the hierarchy sit the competency frameworks which will be defined in the *Compendium of WMO Competency Frameworks* (WMO-No. 1209). The *Guide to Competency* (WMO-No. 1205) describes more fully the relationships between the competencies required for a given job role and qualifications required to enter a profession. The competency frameworks should be the primary guide to assess whether an individual is competent to perform operational activities for any given role, and the *Guide to Competency* (WMO-No. 1205) should be consulted for guidance in using the frameworks.

Although the learning outcomes are presented in several distinct sections, they are interconnected. For instance, hydrologists and hydrological technicians must be able to synthesize knowledge across these boundaries to solve problems and create solutions. It is therefore important to bear in mind that the division of learning outcomes into distinct sections does not imply that the outcomes should be taught in isolation. Cross-disciplinary thinking should be encouraged and may be explicitly included in curricula.

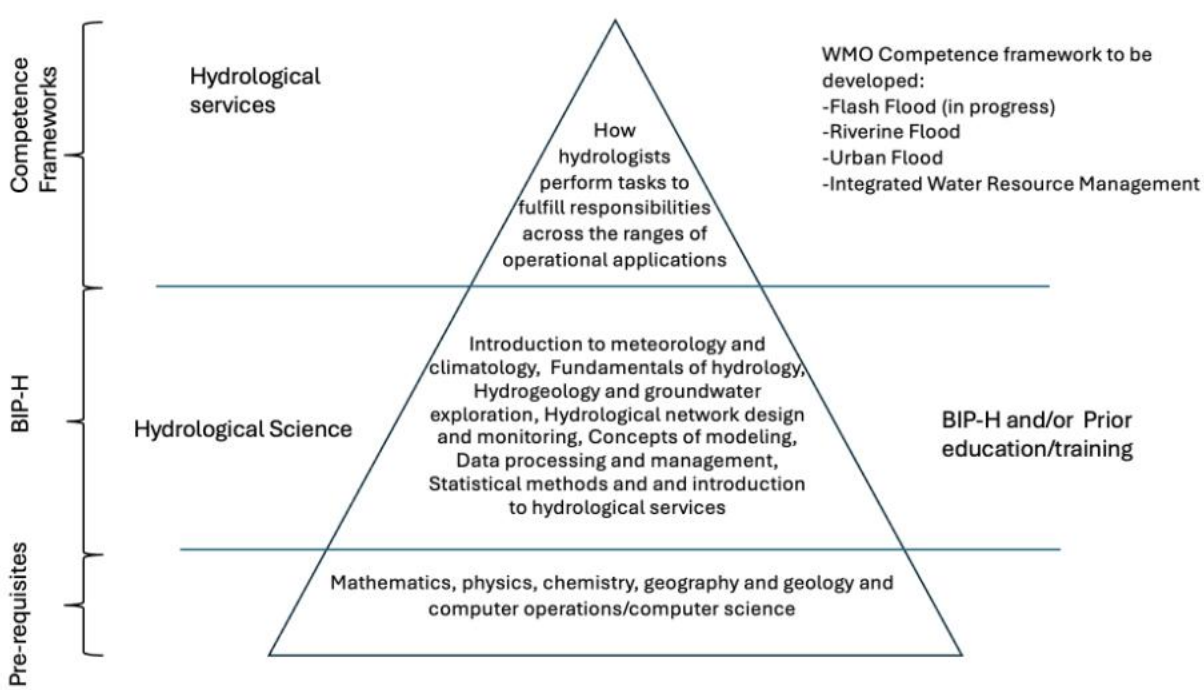

Figure 1.6.1. A hierarchy of education and training for hydrologists

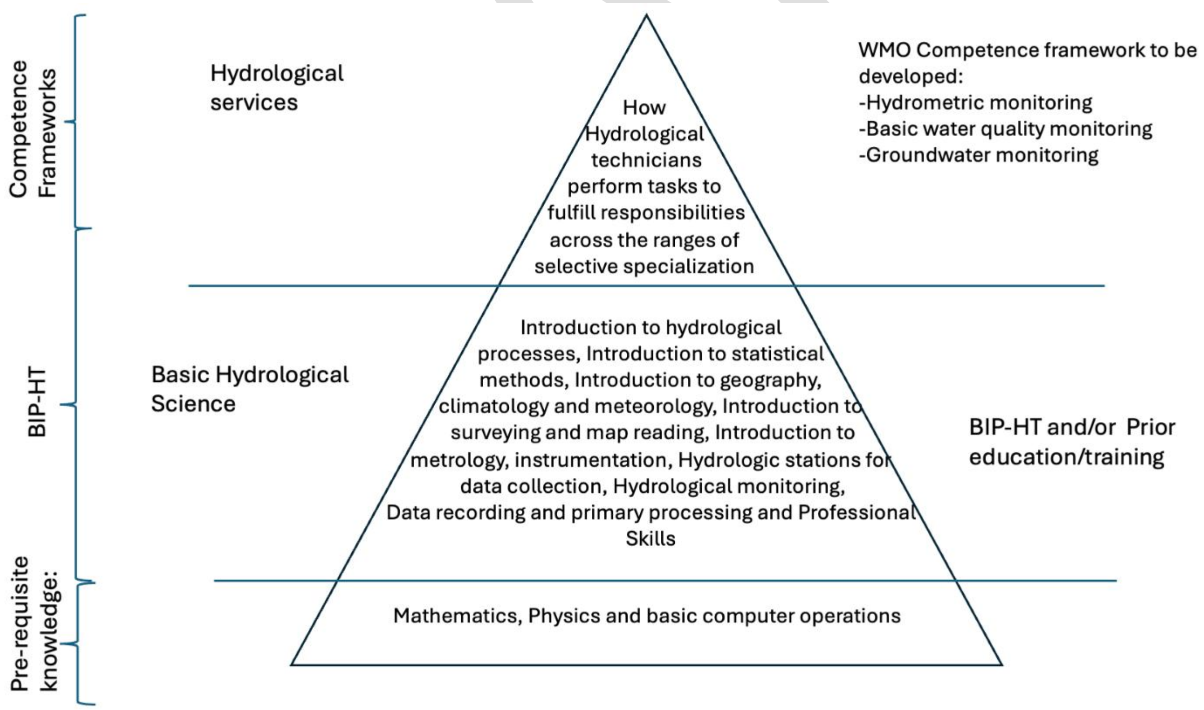

Figure 1.6.2. A hierarchy of education and training for hydrological technicians

1.7 The learning outcome-based approach

The learning outcome-based approach was first introduced in the 2015 edition of the *Guide to the Implementation of Education and Training Standards in Meteorology and Hydrology –Volume I – Meteorology* (WMO-No. 1083) and followed in the current updates of Volume I. It was a change from an outline syllabus to a system of learning outcomes. The reasons for this change remain valid today, as explained in the 2015 edition:

> *[T]he emphasis is on the achievements of the learner rather than the intentions of the instructor or the subjects to be covered as specified in a syllabus. Specific learning outcomes are beneficial both for the instructor and for the students, as they provide clarity about the purpose of the programme of study. They also provide a more robust basis for assessing whether the required learning has taken place*.

This change benefited BIPs by making them better able to describe how knowledge should be demonstrated by students. These more recent version of BIPs go further, using the learning outcome-based approach to define the overall aims of BIPs and making explicit the need for institutions to map the BIP outcomes to their own programme and course outcomes and to map teaching and assessment activities to the course and BIP outcomes.

Learning outcomes have been categorized (see, for instance, Krathwohl & Payne, (1971) into the following three levels of specificity that are interconnected and lie on a continuum:

– Overarching outcomes
– Educational outcomes
– Instructional outcomes

BIP-H and BIP-HT comprise a set of overarching outcomes that, together, specify the philosophy and vision of these BIPs. These overarching outcomes are the desired end; the means to achieve them should be the study and assessment of the educational outcomes in hydrological science.

The BIP-H educational outcomes are grouped into eight main topics:

- Introduction to meteorology and climatology,
- Fundamentals of hydrology,
- Hydrogeology and groundwater exploration,
- Hydrological network design and monitoring,

- Concepts of modelling,
- Data processing and management,
- Statistical methods, and
- Introduction to hydrological services.

The BIP-HT educational outcomes are grouped into nine mandatory topics that address the core knowledge and basic skills for a Hydrological Technician including:

- Introduction to hydrological processes,
- Introduction to Statistical methods,
- Introduction to Geography, climatology and meteorology,
- Introduction to Surveying and map reading,
- Introduction to Metrology, instrumentation and hydrologic stations for data collection,
- Hydrological monitoring,
- Data recording and primary processing, and
- Professional skills

Instructional outcomes are the specific learning outcomes defined at the per-module or per-learning activity level, as part of the process of designing those activities to help students meet the course- or module-level outcomes. They expand the educational outcomes to include the declarative knowledge and lower-level procedural knowledge required to demonstrate the higher-level educational outcomes (see the next section for definitions). BIP-H and BIP-HT include instructional outcomes presented in the tables in this document to guide the breadth and depth of outcomes that institutions might develop. However, BIP-H and BIP-HT do not include instructional outcomes for selective specializations, but a list is provided in this document based on the responses to the WMO BIP-H/HT survey. The relationships among overarching, educational and instructional learning outcomes are summarized in Table 1.1

Table 1.1 The specific level of learning outcomes. Adapted from Anderson et al. (2001).

Level of outcome			
	Overarching	*Educational*	*Instructional*
Scope	Broad	Moderate	Narrow

Time needed to learn	One or more years	Weeks or months	Hours or days
Purpose or function	Provide vision	Design a local curriculum	Prepare lesson/assessment plans
Example of use	Plan an overall programme of study and training	Plan modules or units of instruction	Plan daily activities, lessons, exercises
Included in BIPs?	Yes	Yes	Yes (but only as a guidance)

1.7.1 Defining learning outcomes

As previously noted, modern theories of how learning takes place have moved away from focusing on the intent of the instructor and towards the role and active participation of the learner. Learners are not passive recipients of knowledge given to them through lectures and textbooks, among other methods, but are active agents who engage with learning activities through various cognitive and metacognitive[1] processes, building meaning from them in the context of their prior learning and experience.

We must therefore explicitly identify and specify the body of knowledge we expect a hydrologist or a hydrological technician to learn, and the types of cognitive processes we expect them to apply to make use of that knowledge. To ensure that a common language is used to describe learning outcomes in this explicit fashion, we have used the revised version of Bloom's taxonomy, which is widely used in the field (Anderson, et al., 2001).

The taxonomy consists of two dimensions: the **knowledge dimension** and the **cognitive process** dimension. Both are necessary to fully describe what a student is expected to know and how a student is expected to demonstrate that knowledge. In this section, we briefly discuss these dimensions and how we apply these to BIPs.

Care must be taken not to interpret the taxonomy hierarchically. In the **knowledge dimension**, the different types of knowledge – particularly **declarative knowledge**

[1] That is, "thinking about thinking", or the knowledge people have about themselves as learners, about the processes and techniques they can use to learn, and about when to use those techniques. Metacognition is regulated by conscious planning, monitoring and evaluation of the learning process (Schraw, 1998)

(knowing what) and **procedural knowledge** (knowing how) - are equally important for learning. Likewise, within the **cognitive process dimension**, processes such as remembering or understanding should not be seen as less valuable than applying or evaluating. These processes are complementary, and higher-order cognitive operations require an underlying base of declarative knowledge stored in memory.

The knowledge dimension

The earlier version of these guidelines was largely based on an outline of syllabuses – that is, a high-level list of the topics it was deemed a hydrologist or hydrological technician should learn during their initial education. Since then, although the fundamentals of the hydrological sciences have evolved, transformational change has occurred across the technological domains of pervasive computing, use of remote sensing data such as radar and satellite-based observations, GIS, AI/ML, among others. The societal and economic context in which hydrologists and hydrological technicians operate has also changed significantly.

While the domain of hydrological expertise has grown, cognitive science has transformed our knowledge of the processes through which humans learn, that is, how we organize and structure knowledge.

Declarative knowledge can be broken down into knowledge of facts and knowledge of concepts.

> Factual knowledge consists of the basic terms and facts that hydrologists and hydrological technicians use to communicate about the discipline. This form of knowledge is highly specific, in that pieces of factual knowledge can be isolated as atomic "bits" of information. The learning of factual knowledge is vital both for learning the necessary general types of knowledge and for applying them in the workplace, but care needs to be taken to ensure that students (or instructors) do not overemphasize it. Students must learn to make the connections between and among the various facts, building the schemata that characterizes an "expert" knowledge of the science. A problem that students and their instructors must both address is the ability to transfer and apply facts to the more complex situations a professional will encounter, rather than simply acquiring a body of so-called "inert" factual knowledge.

Conceptual knowledge consists of the more general schemata, theories and mental or conceptual models that include the inter-relationships between and among the facts of the subject matter. A deep understanding of the subject with a clear mental understanding of the myriad facts is a hallmark of an expert in a field and is helpful in the transfer of knowledge to new situations. The bulk of the learning outcomes specified in BIP-H and BIP-HT are related to forms of conceptual knowledge.

Procedural knowledge consists of our knowledge of how to accomplish something, such as solving a quadratic equation, interpreting a hydrograph, or plotting a time series of streamflow using Python. Procedural knowledge is a type of content; it is the "know-how", rather than a cognitive process.

The cognitive process of dimension

The knowledge dimension identifies the content students must acquire, whereas the cognitive process dimension captures the kinds of thinking they use to work with that content. While it is true that retention of knowledge is an important educational goal, the transfer of that knowledge is important for professional qualifications such as BIPs, for both BIP-H and BIP-HT. Transferring knowledge means being able to apply it in different ways to a range of tasks and problems, including in novel situations.

A brief explanation of each of the cognitive processes in the taxonomy is given below, including the definition of the process (Anderson, et al., 2001). Simple examples and notes are provided on how we have represented the process in the BIP learning outcomes. As already noted, there is no inherent hierarchy in this list of processes (remembering complex material is mentally more demanding than creating something simple) and the verbs selected in the outcomes are intended to describe the most common application of the subject knowledge.

It is important to note that in BIP-H and BIP-HT contexts, "**Remember"** and "**Understand"** levels of cognitive process taxonomy are applicable in learning outcomes. Only in some exceptions, "**Apply**" was used to indicate entry-level knowledge and skills for hydrologists and hydrological technicians.

Remember means "retrieve relevant knowledge from long-term memory", such as being able to recognize presented information as being prior knowledge or recalling relevant information. Learning outcomes commonly pair the "remember" cognitive process with factual knowledge and are important in testing the meaningful learning of the fundamental empirical facts and terminology of a discipline.

Examples of learning outcomes using the “remember” process are:

– “Identify appropriate instruments for measuring stream flow.”
– “Recall the definition of a hydrograph.”

Although we do not understate the importance of remembering facts to learning, we have tried to avoid the use of such learning outcomes in BIPs, especially BIP-H. Instead, we have focused on higher-order cognitive processes and left supporting lower-order processes as implied to clearly represent the higher-order thinking that entry-level hydrologists and hydrological technicians are required to have.

Understand means “construct meaning from instructional messages, including oral, written and graphic communication”. “Understanding” in this context refers to the building of connections between the concepts in the instructional messages on the one hand and existing schemas in the long-term memory on the other, giving the student the ability to apply the new concepts with existing knowledge and concepts in mental tasks such as interpreting, exemplifying, classifying, summarizing, inferring, comparing and explaining.

The ability to understand concepts, as defined here, makes up the largest subset of outcomes presented in BIPs, for both BIP-H and BIP-HT, across the more fundamental topics. An example of BIP-H is fundamental to hydrology and its components and the more elementary parts of data processing and management. Where a need exists for both understanding and higher-order processes, we have presented the higher-order process, with the supporting understanding outcome implied. Many of these outcomes require the student to explain a concept. The verb “explain” means more than simply describing the component parts of a concept. Students need to understand the interconnections and feedback between the parts of the system or concept and be able to think through cause-and-effect problems.

A complaint heard from many educators is that learning outcomes such as “a student should understand the continuity equation” are not helpful. Since “understanding” is an internal cognitive process that is impossible to observe and test, we have not used the word as a verb in the outcomes.

Apply means “carry out or use a procedure in a given situation”. Often used with procedural knowledge, these outcomes are used when the ability to carry out a task is required, such as in a calculation. Outcomes at this level can be placed in one of two categories. First, “executing” or “carrying out” is a known procedure for a familiar task. This is the case of exercises in learning situations, where a “recipe” for carrying out a task exists and worked examples will have been presented. Second, implementing a procedure that is unknown requires the student to determine which conceptual knowledge to use in building a strategy that they then use to work out a solution. This is the case for problems in learning situations where the student is required to work out how to solve the problem.

Analyze means “break material into its constituent parts and determine how those parts are related to one another and to an overall structure.” Analyzing can be thought of as an extension of “understanding”, in that it is the process used to determine how ideas are related to one another, to support conclusions with supporting evidence, and to distinguish relevant material from extraneous material. The verbs used that require learners to use the” analyze” process include “select”, “integrate” and “outline.”

Evaluate means “make judgements based on criteria and standards.” Relevant uses of evaluation in hydrological education include detecting inconsistencies within a prognosis and between it and newly available data and determining the most likely best approach to solving a particular problem.

Create means a cognitive process that is often misunderstood as requiring the general of novel ideas or processes. It encompasses functions that are pervasive within hydrology even during education, such as generating hypotheses to account for observed phenomena, planning a small piece of research, or even generating a customer-focused briefing.

1.7.2 Evolution of the BIP learning outcomes

To demonstrate how the contents of this version of BIP-H have some significant changes since 2003, an example of a set of outcomes from fundamentals of hydrology is presented in Table 1.7.2.1. The shift from a list of topics to assessable learning outcomes is clearly represented, as is the change from an academic or theoretical perspective to one grounded in the application of science. The final two rows illustrate the application of the approach described above in terms of the use of higher-order thinking skills. This table shows that it is now possible to design BIP-H courses of study along the spectrum that ranges from the more academic to the more applied, as previously discussed, with all courses being of equal worth. All programs should be designed with employers’ needs in mind and should use a range of evidence-based teaching methods to maximize the transfer of learning.

Table 1.7.2.1 Evolution of the BIP learning outcome example relating to BIP-H

Version	Sample outcomes/topics	Description of knowledge	Cognitive level	Character
WMO-258, 2003	To assist participants to master advanced applications and techniques for describing relationships 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 ungagged catchment problem	Topic-listing, largely conceptual		More theoretical and technical
This Edition	Explain the concept of a catchment (watershed) as the fundamental hydrological unit. Describe hydrological processes at the catchment scale: precipitation, interception, infiltration, evapotranspiration, runoff generation, groundwater recharge, and streamflow. Analyze catchment characteristics (topography, geology, soils, land use/land cover, climate) control process rates and rainfall-runoff response across spatial scales and temporal dynamics. Interpret hydrograph components (rising limb, peak, recession, baseflow) and link their characteristics	Concepts, processes, analysis and interpretation	Remembering, understanding and applying	Theoretical knowledge and skills encouraging critical thinking for applications

	to dominant catchment controls like slope, storage, and flow pathways.			

1.8 Designing teaching and learning, and assessment activities

Traditionally, education and training in university and professional contexts relied on lectures for imparting information. These lectures were supported by tutorials and laboratory work to deepen students' understanding and application of knowledge. In the same way, our approach to curriculum design has evolved from a syllabus describing what knowledge should be covered to a learner-centric, outcome-based approach. Outcome-based approach has become standard practice to have a more diverse range of learning activities in which the student actively applies knowledge.

Given the well-defined learning outcomes set out in Section 1.7, it should be straightforward to design teaching and learning methods and assessment methods that will allow students to achieve those outcomes. Unfortunately, traditional methods such as lectures, which remain widespread, are often not well suited to learning or assessing our outcomes.

This process is illustrated by the concept of constructive alignment (Biggs & Tang, 2011), as shown in Figure 1.8.1 The constructive-alignment approach is based around constructivism and states that, for learning to be effective, three elements need to be both appropriate and relevant to one another:

– Learning outcomes.

– Learning and teaching activities that enable learners to meet those outcomes.

– Assessment methods through which learners can show that they have achieved those outcomes.

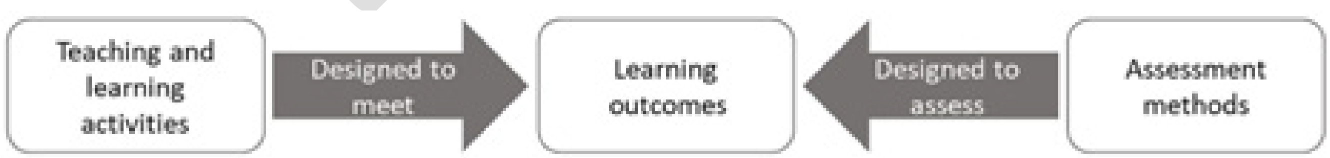

Figure 1.8.1 Constructive alignment between outcomes and activities

1.8.1 Learning declarative knowledge

Consider, as an example, a lecture designed to meet one of the BIP-H learning outcomes in fundamentals of hydrology, namely, "T*o explain the components of the hydrological cycle, processes and their interaction, and quantification at the catchment scale"*. The action verb in this learning *outcome is "explain*", which, as described in section 1.7, requires the student to tell somebody how the components of the hydrological cycle interact with one another in a complex cause-and-effect chain to produce the observed phenomena. The summary in Table 1.8.1.1 is the result of analyzing the lecture to determine the activities being carried out by the instructor on the one hand and the students on the other.

Table 1.8.1.1. Analysis of lecture activities

Instructor activity	Student activity
Introduce	Listen
Explain	Take notes
Elaborate	Understand (but does the student understand correctly and in enough depth?)
Show some slides and a video	Watch, take notes
Questions on slides	Write answers to questions
Conclude	Listen, and possibly ask a question

In this example, the student's role is passive. The desired outcome is for the student to be able to "explain" something, but the student is not given the opportunity or motivation to do any "explaining" in this setting. The lecturer's "explaining" may be good, but the learners are busy receiving declarative knowledge that they are working hard to "remember". A disciplined student with a good study technique and enough spare cognitive load may internally build the schema, including connections between the information they are receiving, and may explain the whole; otherwise, the actual outcome is entirely different from the intended one ("remembering" versus "explaining").

Learning approaches that keep the student active and in control of the process should be preferred over passive experiences to support the acquisition of the body of declarative knowledge required in hydrology. A combination of instructor-led and self-led learning can be used. The key is that--whether listening to a lecture, actively reading, or participating in group discussions-- the student is using the appropriate metacognitive skills to actively retrieve and use the required knowledge. If the learning outcome is to recall a certain fact, then the student should be doing "*recall"*; if the outcome is to explain, the student should be doing "*explaining*"; in either case, the teaching and learning activity needs to be aligned with the learning outcome.

1.8.2 Learning procedural knowledge

Many of the learning outcomes for both BIP-H and BIP-HT are written in terms of lower and Mid-level cognitive process skills; the procedural knowledge associated with the "*remember*", "*understand*", and "*apply*" categories in the taxonomy really defines an entry-level hydrologist or a hydrological technician.

Teaching and learning activities must activate those cognitive processes in the student for the student to master both the knowledge and the use of those very processes. Examples of teaching and learning activities that encourage or require the use of the processes include case study-based learning, group and individual projects, and workplace-based learning (known as placements, internships and practicums, among other terms).

Development of the necessary metacognitive abilities such as problem-solving are likely beneficial to the learning of procedural knowledge but are unfortunately often not taught explicitly.

1.8.3 Assessment

Just as the methods used in teaching and learning must be aligned with the learning outcomes, so must the means of assessing learning. Clear learning outcomes that specify the knowledge and cognitive process needed should be made available to learners to allow them to self-assess and gauge their progress. The aim of constructive alignment between the learning outcome and the assessment item should make devising those assessment items far easier but might require innovation in the assessment methodology.

If students are being asked to explain a piece of knowledge, then assessment items should give them the opportunity to explain it. Similarly, learning outcomes that require students to evaluate a situation must be assessed in ways that test students' critical thinking and analytical ability. It is often easier to test students' ability to recall declarative knowledge than their application of procedural knowledge, but if the outcome calls for procedural knowledge, that is what needs to be tested.

As described in the previous subsection, activities such as the development of case studies, conducting individual research projects, and the presenting results are useful for learning are also useful for assessing of a range of higher-order cognitive processes.

1.9 Curriculum design

Institutions should use BIPs as a foundation and define their own detailed learning outcomes, adapting them to regional, national, and local roles and activities. When creating a new program or reviewing existing ones, institutions should use a structured, systematic approach to curriculum design, such as the approach illustrated in Figure 1.9.1. This helps to ensure that each program meets BIP requirements and clearly illustrates students and employers how the program will benefit them. An integrated, systematic approach to curriculum design should also ensure that the connections and interdependencies between various components are made explicit, and that activities are designed that use those connections. This will give students an overall picture of how the hydrological cycle works and how NMHSs and other hydrological service providers contribute to society.

This guide provides broad instructional outcomes on prerequisites and mandatory topics, but it does not provide detailed module-level instructional outcomes that include the detailed guidance needed by instructors which depend on local contexts, national educational systems, and teaching approaches. Designing learning and assessment activities is critical and should intentionally use evidence-based teaching methods and appropriate educational technologies.

BIP-H and BIP-HT do not define a recommended specific program length since programs vary widely in format, goals, and student backgrounds. What matters is achieving the learning outcomes that mark a person as a hydrologist or hydrological technician, not the amount of time spent on training.

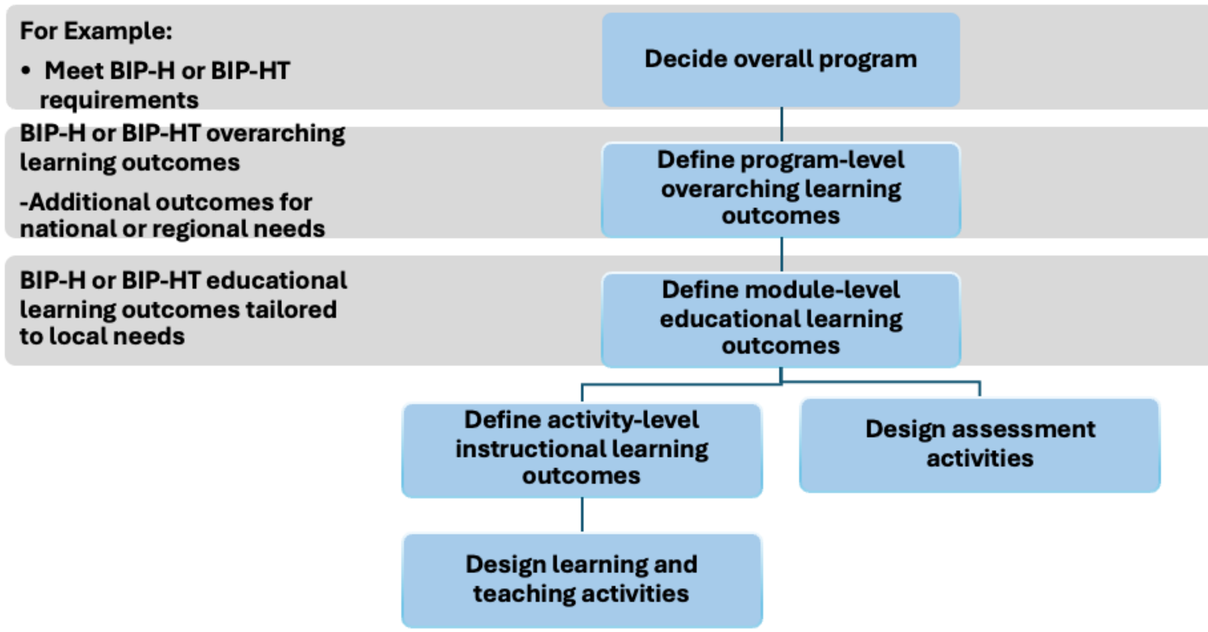

Figure 1.9.1 Mapping of BIPs to program outcomes

1.10 Inclusive teaching and assessment

The WMO Strategic Plan *2024-2027,* Objective 4.2 focuses on developing and sustaining core competencies and expertise. The strategic plan states that:

"There is a growing deficit in the capability and numbers of adequately educated and trained staff needed to provide weather, climate, hydrological and related environmental services in many countries and territories. Additionally, rapid advances in scientific innovation and technological developments and means for public communication require corresponding and continuous training of NMHS personnel. WMO will increase its training and long-term education activities to help Members to obtain and maintain the competencies needed."

A specific outcome under this objective is directly related to BIP-H and BIP-HT that strengthens the qualifications and competencies of NMHSs and related institutions for effective service delivery. To contribute towards this objective and focus on the objectives described, it is important to have equal access to education and training programs and for learning and teaching materials and assessments to be fully accessible to all members and representatives of the diversity of the potential student base. Programs that are inclusive should be accessible to part-time students, including for those who need childcare, facilitating gender equality, in particular.

Having clear learning outcomes coupled with transparent and fair assessment policies benefits student attainment and contributes to a more inclusive culture.

1.11 Case studies in the implementation of BIPs

The sections of BIP-H and BIP-HT are not intended to mandate a course structure or to rigidly define the contents of a program of study. Since each WMO Member, NMHS, university or other training institution will have its own requirements, systems of regulation and education systems, it is necessary to develop course curricula and outcomes that are aligned with these criteria. Courses will also include content, such as other complementary subjects, aimed at meeting an institution's interests and to ensure their graduates have a well-balanced education.

1.11.1 Implementation of BIP-H

The outline programs described below are examples of how BIP-H might be implemented, but other structures are equally valid.

Case 1: Undergraduate program in hydrology

One way of implementing BIP-H is by placing it at the core of an undergraduate program in hydrology. An outline example of such a program is illustrated in Figure 1.11.1.1 In this example, it is assumed that hydrology is combined with other fields such as earth sciences in undergraduate programs. However, there are only a few universities that offer a degree in hydrology around the world. Mostly hydrologists come from different backgrounds of science and civil engineering, and many of these undergraduate curricula only include a few introductory hydrological courses in the curriculum.

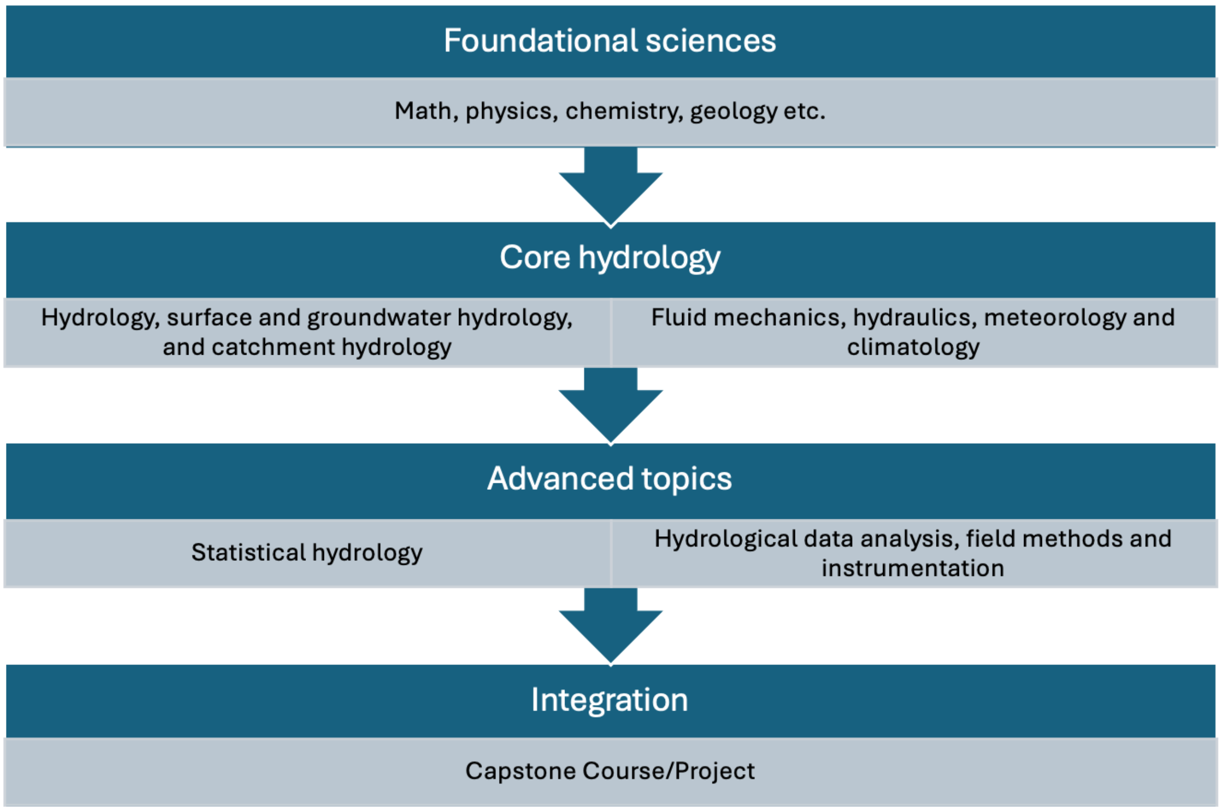

Figure 1.11.1.1 Schematic of an undergraduate program in hydrology

Case 2: Postgraduate program in hydrology

Another common way of implementing BIP-H is by placing it at the core of a masters-level postgraduate program in hydrology, typically over a 1- or 2-year period. An outline example of such a program is illustrated in Figure 1.11.1.2. In this example, it is assumed that students have a first degree in a relevant field and completed undergraduate courses in mathematics, chemistry and physics, and other related pre-requisites to enable them to progress to this level and intensity of study.

Post-graduate programs in hydrology may also include additional course work of electives which are beyond the scope of BIP-H and may contribute towards a competency framework.

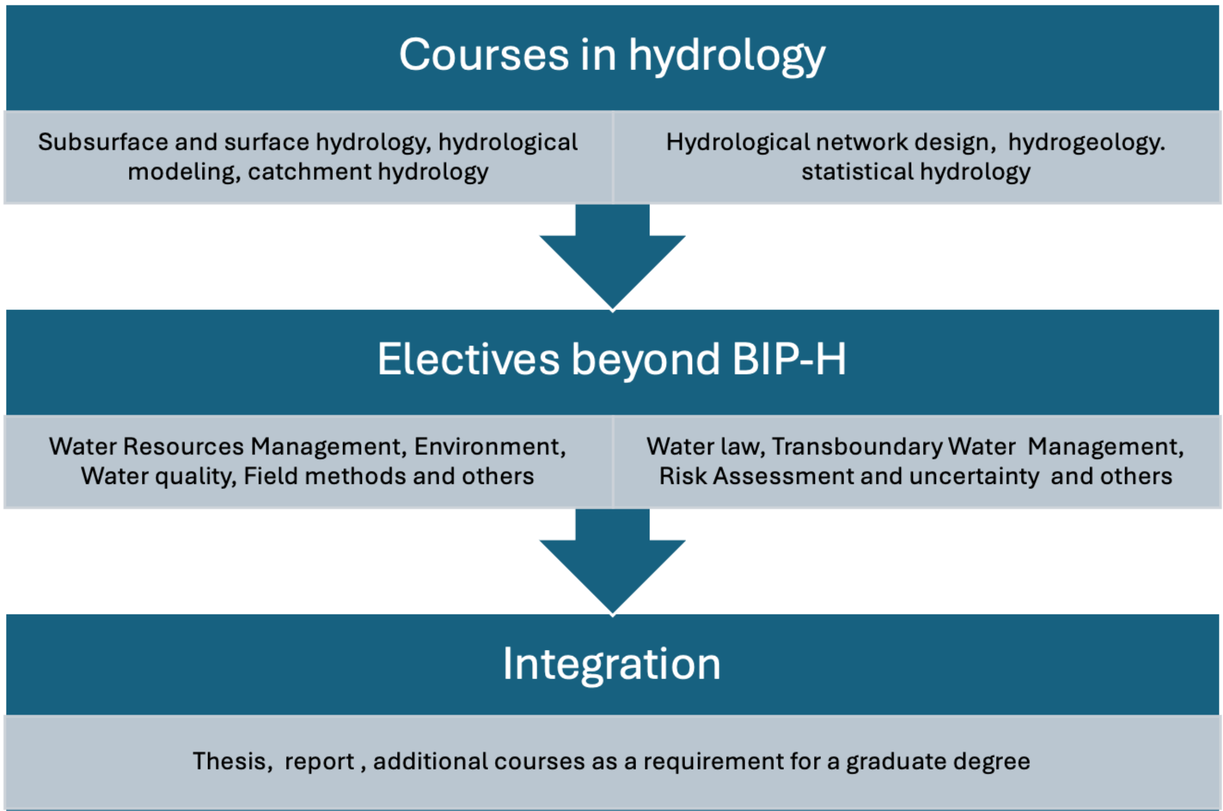

Figure 1.11.1.2 Schematic of a graduate program in hydrology

Case 3: In-service training at a NMHS, RTC, university and/or other training organizations

This example refers to training delivered at one or combination of an NMHS, Regional Training Center (RTC), university, and/or other training organization providing studies at university level. It is assumed that students are either graduates in a physical science subject or staff employed as hydrological technicians or in other roles who have the pre-requisite education, possibly gained in service (for example through accredited online programs or at local colleges).

Although the level of education needed to complete the BIP-H topics will necessarily be comparable to undergraduate hydrology study, these programs generally do not result in the award of academic credits or a degree. Instead, they provide focused, practice-oriented training aligned with BIP-H and institutional requirements.

1.11.2 Implementation of BIP-HT

Members have used various education and training approaches to train their hydrological technicians, from specific formal-education training program in hydrology at a technical school, RTC, other training organizations providing training fully compliant with BIP-HT, to vocational and on-the-job training (or a combination of the two) in hydrological observations and measurements. Regardless of the approach adopted, individuals must meet the BIP-HT requirements.

1.12 BIPs at later stages of a career

The requirements specified by BIP-H and BIP-HT have been presented as if they are normally met by an individual taking an initial program of study at a university or training institution. This would usually happen before or shortly after the person takes up employment at an NMHS. In practice, however, satisfying the requirements to be a hydrologist or hydrological technician might be achieved mid-career.

For example, hydrological technicians who have acquired substantial knowledge of hydrology based on their initial training, continuous professional development and operational experience may want to take a program of study that allows them to be classified as hydrological technicians. In that case, many of the learning outcomes specified by BIP-H will have already been achieved. Provided that recognition of prior learning can be formally established and recorded, the program of study needs only to cover those learning outcomes that have not already been achieved. Establishing and recording of prior learning may be undertaken by those responsible for training within an NMHS, when the NMHS is designated (if so, required by the national educational regulator or department) as a “recognition-of-prior-learning” centre. The same approach applies to people whose initial training does not cover the entire BIP-HT, but who later in their careers decide they want to be classified as hydrological technicians. The specific national or institutional regulations and requirements of a particular country will determine whether recategorization that takes recognition of prior learning into account is accepted in that country.

2. BASIC INSTRUCTION PACKAGE FOR HYDROLOGISTS

This part of the document contains guidance on how to implement the learning outcomes of BIP-H that will be included in the *Technical Regulations* (WMO-No. 49). This section provides a summary of the intention behind the outcomes as written and includes more detail on the topics that might be included in a program of study to meet the learning outcomes. The detail provided in this chapter is neither exhaustive nor intended to constrain WMO Members in the definition of program. The learning outcomes in the lists defines BIP-H, not the explanatory detail in the tables in the lists.

Hydrologists need to be able to apply high-level creative problem-solving, think critically, produce incisive analyses, and carry out routine and non-routine tasks independently. It is these higher-order cognitive processes, and a deep understanding of hydrological processes, that graduates of the BIP-H program must develop.

For this reason, the lower-order thinking skills associated with the “remember” level of the taxonomy as defined in Section 1.7.2 (recognizing and recalling) are avoided where possible. Of course, there is a great deal of declarative knowledge – both empirical knowledge and terminology – which is important for hydrologists to know, and which provides a vital foundation for higher–order skills. In most cases, this factual knowledge is implied rather than explicitly stated here.

We have also been circumspect in using verbs associated with the “understanding” cognitive process level, such as “explain” and “describe”. These verbs are often misunderstood by students and instructors alike as requiring simple recitation of an explanation, derivation, etc., when they mean the ability to construct cause-and-effect system models to demonstrate understanding of a concept. The definitions given in the previous chapter should be used to determine what the verbs in these outcomes mean within the context of BIP-H.

2.1 Interpretation

In this chapter, text enclosed in grey-shaded boxes, like this example, comprises excerpts for inclusion in the next edition of the *Technical Regulations* (WMO-No. 49), Volume III. The texts will have the regulatory status of standard practices and procedures.

The rest of this section includes narrative and suggested instructional outcomes. These outcomes are intended to guide WMO Members implementing BIP-H and HT, but do not have regulatory status.

2.2 Overarching learning outcomes

The overarching learning outcomes summarize the overall philosophy of BIP-H by describing how professional hydrologists think and how they use the data and tools for providing services. The key attributes and skills described in this section distinguish professional hydrologists, regardless of what kind of role they might undertake.

The outcomes described here are not intended to describe any specific role and do not make any assumptions regarding the context within which an individual might eventually be employed. They are not necessarily intended to map directly to modules or units of study. Rather, they should permeate a program of study as a whole and be used to assess the program to ensure that individual units of study contribute to the program's broader aim of embedding hydrological thinking and practice and establishing links between theory, the real situation, and the provision of scientific and professional services, to the benefit of society.

Hydrologist shall be able:

- To describe the major components of the hydrological cycle and their fundamental processes for assessing the availability and movement of water under natural and anthropogenic conditions.
- To explain data acquisitions, both in situ observations and remotely sensed data, and their potential utility for assessing hydrological conditions and trends, as well as for input to hydrological analyses and modelling at appropriate temporal and spatial scales.
- To explain the basic concepts of hydrological analysis, modelling, forecasting, and their limitations, considering the impacts of data availability and suitability of analytical methods and models.
- To demonstrate effective communication of relevant hydrological information for stakeholders.

These learning outcomes should be achieved through learning and assessment of the topics of hydrology described later in this section supplemented where necessary by the learning outcomes and other outcomes as required to meet national needs, and supported by the advice on basic mathematics, chemistry physics and other topics also found in this part of the guidance.

2.3 BIP-H Prerequisites

2.3.1 Mathematics

Mathematics forms the essential foundation for any basic instruction package in hydrology, serving as the language through which natural processes are quantified, analyzed, and predicted. From algebra and geometry to calculus and statistics, mathematical tools enable hydrologists to model water flow, interpret hydrographs, calculate water balances, and assess uncertainty in measurements. Without a solid grounding in mathematics, the ability to translate complex hydrological phenomena into clear, actionable insights would be severely limited. Thus, mathematics is not merely a prerequisite but a critical competency that underpins the rigor, accuracy, and professional credibility of hydrological practice.

For these reasons, the learning outcomes regarding mathematical prerequisites are the following:

Hydrologists shall be able to:

- Employ mathematical language, concepts, and techniques used in basic hydrological bibliography and teaching materials.
- Develop abstraction and mathematical reasoning skills to apply knowledge in problem-solving, adapt methods to new contexts, justify decisions with logical arguments, and communicate the reasoning clearly using mathematical language.
- Interpret and apply basic statistical measures used to summarize hydrological data and analyse errors.

The following table is intended to help define instructional learning outcomes within modules in mathematics. It is meant to indicate the level of complexity and the depth of learning needed to acquire the prerequisite knowledge and skills in mathematics needed to pursue studies to become a hydrologist. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the prerequisites of the modules in mathematics

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Mathematics	
Algebra and Geometry	- Solve simple geometric problems. - Determine the slope between two points. - Describe the trigonometric functions. - Apply vector operations to determine the equation of a line or plane in space. - Manipulate equations, polynomials, and factorization. - Handle expressions containing logarithms and exponentials. - Determine the solution to a system of equations with two variables.
Differential equations	- Classify ordinary differential equations, identifying initial value and boundary value problems, as well as their application in mathematical models. - Interpret the solutions of linear and nonlinear differential equations in the context of initial value and boundary value problems, analyzing their meaning in applied mathematical models. - Explain the basic forms of partial differential equations and describe their physical meaning. - Interpret the use of differential equations to solve hydrological problems and justify their use of mathematical models for real-world systems.
Differential calculus of one variable	- Represent functions algebraically and graphically. - Analyse limits of functions to interpret their meaning and determine continuity at given points. - Apply differentiation rules and interpret results in terms of rates of change.

Integral Calculus of one variable	- Explain the methods of integration and their combinations. - Interpret the definite integral as a tool for estimating the area under a curve using finite sums and for understanding the meaning of the average value of a function over an interval.
Integral Calculus of several variables	Explain the fundamental concepts of vector calculus and functions of several variables. Apply the gradient and differentiation rules to analyze functions and extrema. Distinguish between multiple, line, and surface integrals to solve volume, work, and flow problems using fundamental theorems.
Sequences and numerical and power series	Explain the representation of numerical sequences and distinguish the concepts of convergence, divergence to infinity, and calculation of limits. Differentiate numerical and power series. Employ numerical series to study convergence/divergence and power series to approximate a function.
Statistics	Introduction to probability theory, random variables, and probability distributions. Regression and correlation to analyse relationships between variables in water resources studies. Time Series.

2.3.2 Physics

Hydrology is fundamentally a physical science, grounded in the laws that govern motion, energy, and mass transfer in natural systems. Understanding water movement, storage, and transformation in the atmosphere, on the land surface, and in the subsurface requires a basic grounding in physics. However, BIP-H is not intended to educate physicists; physics is treated as a supporting tool that enables hydrologists to understand and apply hydrological concepts rather than an end.

For these reasons, BIP-H includes physics learning outcomes only in areas that directly underpin hydrological processes and analysis. Institutions may extend beyond these minimum requirements to suit their educational approach or to prepare learners for advanced study.

Hydrologists shall be able to:

- Explain fundamental physical principles—including mechanics, fluid mechanics, thermodynamics, wave motion, and electromagnetic radiation—that govern water movement and energy transfer in natural and human-modified systems.
- Apply these principles to solve basic hydrological problems, using simple mathematical tools to relate physical concepts (e.g., pressure, energy conservation, heat transfer) to real-world fluid systems.

The following table is intended to help define instructional learning outcomes within modules in physics. It is meant to indicate the level of complexity and the depth of learning needed to acquire the prerequisite knowledge and skills in physics needed to pursue studies to become a hydrologist. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the prerequisites of the modules in physics

Physics	
Mechanics and Kinematics	Identify and apply Newton’s laws to simple hydrological scenarios (e.g., forces acting on flowing water). Explain concepts of work, energy, and momentum and relate them to water movement.
Fluid Mechanics	Define hydrostatic pressure and buoyancy.

	Explain why pressure changes with depth. Distinguish between laminar versus turbulent flow. Apply continuity principles in simple flow systems. Use conservation of mass and energy to derive and apply the water balance equation in hydrological analysis. Interpret how physical principles are embedded within simple hydrological models and measurements. Interpret how physical laws underpin simple hydrological models and use them to analyze water movement and storage.
Heat Transfer and Thermodynamics	Explain basic heat transfer processes (conduction, convection, radiation) and their role in evaporation and soil-water-atmosphere interactions. Apply simple energy balance concepts in hydrological contexts.
Waves and Oscillations	Identify basic wave properties (wavelength, frequency, amplitude) and give examples relevant to hydrology (surface waves, tides).
Electromagnetic Radiation	Explain the importance of solar radiation for evaporation and climate. Recognize basic concepts of reflection and absorption by water, soil, and vegetation.
Applications of Physical Principles in Hydrological Modelling	Outline the components of the water balance equation and explain their physical basis. Apply conservation of mass to calculate changes in water storage using precipitation, runoff, and evapotranspiration data.

	Recognize how basic physical laws (e.g., Darcy’s law, energy balance) are incorporated into simple hydrological models for catchment-scale analysis.

2.3.3 Chemistry

Fundamentals of Chemistry provide the essential scientific foundation for understanding water quality and the chemical processes governing hydrological systems. A working knowledge of core chemical principles enables hydrologists to interpret the composition, behaviour, and transformation of solutes in surface water and groundwater. This section outlines the minimum chemistry competencies required to support the study of hydrology, including atomic structure, chemical reactions, aqueous equilibria, solution chemistry, and introductory analytical methods. The instructional outcomes presented are intended to guide curriculum design by identifying key areas of knowledge necessary for analyzing natural waters and linking chemical processes to hydrological phenomena.

Hydrologists shall be able:

- To explain basic chemical principles needed to understand water quality and fundamental hydrological processes.
- To describe introductory analytical methods to interpret chemical characteristics of natural waters.

The following table is intended to help define instructional learning outcomes within modules in chemistry. It is meant to indicate the level of complexity and the depth of learning needed to acquire the prerequisite knowledge and skills in chemistry needed to pursue studies to become a hydrologist. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the prerequisites of the modules in chemistry

Chemistry	
Atomic Structure and Chemical Bonding	Describe basic concepts, atoms, elements, compounds, isotopes, types of chemical bonding, and periodic table trends.
Stoichiometry and Chemical Reactions	Apply quantitative chemical relationships and simple reactions to interpret solute transport, mineral

	dissolution, precipitation, and transformation processes in water.
Chemical Equilibrium in Aqueous Systems	Explain equilibrium concepts governing acid–base reactions, solubility, and ion exchange processes in surface water and groundwater.
Solution Chemistry and Concentrations	Perform concentration calculations, dilution, and unit conversions required for water quality assessment and chemical mass balance.
Introductory Analytical Chemistry	Describe basic analytical techniques used to characterize the chemical composition of natural waters.
Water Quality Measurement Techniques	Describe common water quality parameters and measurement methods applied in field and laboratory hydrological studies.

2.3.4 Geography and Geology

Geographical, cartographic, surveying, GIS and geological knowledge provides the spatial foundation essential for hydrologists to delineate catchments, site observation networks, interpret terrain influences on water flow, and assess geological controls on water resources. This prerequisite topic equips learners with practical skills to read maps, conduct basic field surveys, and use spatial tools required for hydrological fieldwork, data collection, and catchment characterization in operational settings.

The topic covers fundamental geographic concepts, map reading and interpretation, basic surveying techniques for hydrological applications, elementary GIS operations for catchment analysis, and geological principles influencing water movement and storage. Learners develop competence in identifying physical and manmade features on topographic products, extracting terrain attributes, measuring field elevations and distances, and recognizing how geology controls runoff generation, infiltration capacity, and aquifer characteristics.

Hydrologist shall be able:

- To describe the basic geographical, geological, and topographic setting of hydrological catchments at local to regional scales.
- To interpret maps, plans, and remotely sensed products to support hydrological observation, data collection, and simple analysis.

- To apply elementary surveying and GIS techniques to derive spatial information needed for hydrological measurements and assessment.

The following table is intended to help define instructional learning outcomes within modules in geography and geology. It is meant to indicate the level of complexity and the depth of learning needed to acquire the prerequisite knowledge and skills in geography and geology needed to pursue studies to become a hydrologist. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the prerequisites of the modules in geography and geology

Geography, Cartography, Surveying, GIS, and Geology	
Basic Geography	Recall fundamental geographic concepts (latitude/longitude, map scale, projections, contours, watershed boundaries). Identify physical features (rivers, divides, landforms) and human features (settlements, infrastructure) on topographic maps and images.
Cartography	Describe map elements (legends, scales, north arrows, contour intervals) and their use in hydrological planning. Interpret topographic contours to determine elevations, slopes, and catchment drainage patterns.
Surveying	Recall basic surveying terms (bearing, chainage, level, benchmark, reduced level). Apply simple leveling and distance measurement techniques for hydrological field surveys (stream cross-sections, gauge locations)
GIS Fundamentals	Identify common GIS data types (vector, raster, DEM, satellite imagery) used in hydrology. Apply basic GIS functions (zoom, pan, layer selection, area/length measurement, simple queries) to delineate catchments and extract terrain attributes.
Geology	
Basic Geology	Recall basic rock types (igneous, sedimentary, metamorphic) and soil classifications relevant to hydrological processes. Describe how geological structures (faults, folds, aquifers) influence groundwater flow and surface runoff generation.

2.3.5 Computer Operations / Computer Science

Computer science knowledge is indispensable for hydrologists to process data, perform numerical analysis, visualize spatial-temporal patterns, and collaborate across networks in water resources assessment and modelling. This prerequisite topic builds essential computer skills for handling hydrological information systems, ensuring efficient data workflows from acquisition through analysis and dissemination in research and operational hydrology.

The topic addresses fundamental hardware architecture and operating systems for scientific computing, key software platforms including spreadsheets, databases, and GIS for hydrological applications, file management with common data formats and error-checking procedures, basic data visualization techniques for pattern recognition, network infrastructure for data transfer and cloud collaboration, and data management practices such as version control, backups, and standardized documentation structures.

Hydrologist shall be able:

- To describe fundamental computer systems, software applications, and data management practices essential for hydrological computing and analysis.
- To apply basic computing tools and procedures for data handling, visualization, and sharing for hydrological purposes.
- To recognize the role of networks, data formats, and version control in supporting reliable hydrological data processing and sharing.

The following table is intended to help define instructional learning outcomes within modules in computer operations/computer science. It is meant to indicate the level of complexity and the depth of learning needed to acquire the prerequisite knowledge and skills in computer operations/computer science needed to pursue studies to become a hydrologist. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the prerequisites of the modules in computer operations/computer science

Computer Operations / Computer Science	
Computer Hardware and Systems	Recall basic computer architecture (CPU, memory, storage) and operating system functions relevant to scientific computing.

	Identify hardware components suitable for hydrological data processing and field instrumentation interfaces.
Software Applications	Identify key software platforms for hydrology (spreadsheets, word processors, databases, GIS interfaces). Describe functions of common tools (Excel, Access, QGIS) for data entry, analysis, and reporting in hydrological applications.
File Management and Data Formats	Describe file organization principles, directory structures, and common data formats (CSV, Excel, text, binary) used in hydrology. Explain procedures for structured data entry, automated formatting, and basic error checking in digital datasets.
Data Visualization	Recall fundamental data visualization techniques (tables, charts, graphs) available in spreadsheets and GIS software. Interpret tabular and graphical outputs from computational tools to identify patterns in hydrological datasets.
Computer Networks	Explain how networks, internet infrastructure, and cloud services support hydrological data transfer and sharing. Identify basic network protocols (HTTP, FTP) and security practices for accessing hydrological data repositories.
Data Management Practices	Explain version control concepts and backup procedures for maintaining hydrological datasets. Apply simple file naming conventions and folder structures for organized hydrological project documentation.

2.4 Mandatory topics

2.4.1 Introduction to Meteorology and Climatology

The science of meteorology and climatology provides a physical basis for understanding how atmospheric and climatic processes influence the hydrological cycle across spatial and temporal scales. Hydrologists routinely draw on meteorological and climatological knowledge to interpret weather and climate data, assess water availability, understand hydrological extremes such as floods and droughts, and support forecasting, planning, and risk management. Processes occurring in the atmosphere and the cryosphere—including precipitation formation, temperature variability, snow and glacier dynamics, and large-scale climate variability—directly control key hydrological processes, such as runoff generation, infiltration, evaporation, and river discharge.

The learning outcomes in this section of BIP-H are not intended to produce professional meteorologists or climatologists. Rather, they aim to ensure that hydrologists develop a basic understanding of key meteorological, climatological, and cryosphere concepts, and can interpret meteorological and climate data and products relevant to hydrological analysis. This grounding enables hydrologists to make informed use of observations from ground-based instruments, remote sensing, and climate products, to understand their limitations, and to communicate associated uncertainties clearly to users and decision-makers.

Hydrologists shall be able:

- To describe key meteorological, climatological, and cryosphere processes that influence hydrology.
- To interpret meteorological and climatological data and products to support hydrological analysis.

The following table is intended to help define instructional learning outcomes within modules in introduction to meteorology and climatology. It is meant to indicate the level of complexity and the depth of learning needed to acquire the knowledge and skills in this topic that are necessary to become a hydrologist. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the requirements in Introduction to Meteorology and Climatology

Introduction to Meteorology and Climatology	
Atmospheric structure and composition	Identify the main layers of the atmosphere (troposphere, tropopause,

	stratosphere) and outline their relevance to the water cycle and hydrological processes.
Weather Systems and Precipitation	Identify major precipitation types (convective, frontal, orographic), explain basic cloud formation processes, and relate these to runoff and infiltration.
Climate Variability and Change	Recognize key drivers of climate variability (e.g., El Niño–Southern Oscillation (ENSO), interpret simple climate trend graphs, and understand implications for hydrological extremes such as floods and drought, and water availability.
Meteorological variables	Identify and define key meteorological variables (e.g. temperature, pressure, humidity, wind speed and direction) and explain their role in atmospheric dynamics and their influence on the hydrological cycle
Weather and climate fundamentals	Explain the difference between weather and climate and their relevance to hydrological processes
Meteorological instruments	Identify basic meteorological instruments (e.g., rain gauge, thermometer, barometer, anemometer) and their role in collecting data for hydrological analysis.
Local wind systems	Describe sea breeze, land breeze, and valley winds and their potential influence on local hydrological conditions including rainfall and evaporation.
Climate-data quality control	Understand basic procedures and steps for checking climate data quality,

	including site assessment and data storage.
Cryosphere components; Glacier and seasonal snow dynamics	Understand the cryosphere as a key component of the Earth system and its critical role in influencing hydrological processes. Explain how glacier mass balance and seasonal snowpack affect river discharge and water availability. Describe glacier mass balance and snowpack dynamics.
Snow and ice proceses	Identify key meteorological factors influencing snow accumulation, snowmelt, and runoff. Understand snowpack dynamics, glacier melt, and their influence on runoff and water availability in cold and mountainous regions.
Remote Sensing for Climate, Meteorology	Explain how satellite and airborne sensors are used to monitor atmospheric and surface variables and define Quantitative Precipitation Estimates (QPE) as precipitation data products derived from in situ observations, remote sensing and radar observations. Describe how QPEs are used as inputs in hydrological models to simulate runoff, streamflow, and support flood forecasting and water resource management. Outline the utility of remote sensing, especially in data-sparse regions.

Meteorological data sources	Outline common sources of meteorological data (satellite, radar, ground-based in situ stations) and their application in hydrological studies.

2.4.2 Fundamentals of Hydrology

Fundamentals of Hydrology provide essential knowledge of the hydrological cycle and its components, approaches for monitoring these and their interactions. This topic also introduces water balances and various hydrological analyses commonly used in operational hydrology. This foundational topic equips learners with the understanding of water movement, storage, and hydrological processes, approaches for accurate data collection, catchment assessment, and basic hydrological analyses in operational settings.

This topic addresses the components and interactions of the hydrological cycle, including precipitation partitioning, evapotranspiration, infiltration, runoff generation, groundwater recharge, and streamflow formation at the catchment scale. Learners develop skills in characterizing catchments through physiographic and land use analysis, applying water balance methods to quantify inputs/outputs/storage changes, and using analytical techniques such as hydrograph separation and flow regime analysis. Measurement principles for key processes and factors influencing catchment geomorphology along with some important hydrological analyses complete this practical foundation for hydrological fieldwork, data interpretation, and analyses.

Hydrologist shall be able:

- To explain the components of the hydrological cycle, processes and their interaction, and quantification at the catchment scale
- To explain the concept of water balance and demonstrate its application in hydrological analysis, and
- To describe analytical methods and techniques to analyze the flow regime.

The following table is intended to help define instructional learning outcomes within modules in fundamentals of hydrology. It is meant to indicate the level of complexity and the depth of learning needed to acquire the knowledge and skills in this topic that are necessary to become a hydrologist. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the requirements in Fundamentals of Hydrology

Fundamentals of Hydrology	
Hydrological cycle and its components	Explain the components and processes of the hydrological cycle and their interconnections using correct terminology. Recognize the various storages and fluxes: precipitation, evaporation, infiltration, runoff, and groundwater recharge.
Catchments characteristics and its interaction with hydrological processes	Explain the concept of a catchment (watershed) as the fundamental hydrological unit. Describe hydrological processes at the catchment scale: precipitation, interception, infiltration, evapotranspiration, runoff generation, groundwater recharge, and streamflow. Analyze catchment characteristics (topography, geology, soils, land use/land cover, climate) control process rates and rainfall-runoff response across spatial scales and temporal dynamics. Interpret hydrograph components (rising limb, peak, recession, baseflow) and link their characteristics to dominant catchment controls like slope, storage, and flow pathways.
Measurement and estimation of hydrological processes	Identify sources of hydrological data including rain gauges, stream gauges, evaporation pans, lysimeters, piezometers, and remote sensing products relevant to catchment studies. Describe measurement techniques for precipitation, evapotranspiration, streamflow, infiltration, and groundwater levels with appropriate sampling frequencies. Apply empirical methods and analytical techniques to estimate runoff volumes and discharges from measured data.
Water balance estimation	State the components and sequential steps to compute catchment water balance using observed precipitation, streamflow, and change in storage data.

	Analyze rainfall-runoff relationships to identify dominant runoff generation mechanisms. Explain frequency analysis of streamflow data
Hydrological Analysis	Outline procedures for hydrograph separation and unit hydrograph derivation from observed rainfall-runoff records. Describe development, interpretation, and applications of Flow Duration Curves (FDCs) for assessing water availability. Outline procedures for Intensity-Duration-Frequency (IDF) curve development from rainfall data and their use in hydrological design applications.
Catchment water quality	Recall natural (geology, climate) and anthropogenic (agriculture, urbanization) factors affecting water quality parameters in catchments. Summarize the interplay between hydrological processes, surface runoff, and sediment/nutrient transport dynamics. Recognize impacts of land use changes (urbanization, agriculture, infrastructure) on water quality and erosion processes.

2.4.3 Hydrogeology and groundwater exploration

Groundwater is an essential component of the hydrological cycle and, as such, directly influences hydrological and meteorological processes at the local and regional levels. Although not visible to the naked eye, it constitutes 97 percent of the planet's readily accessible freshwater, supplies more than 40 percent of irrigation demand, and provides approximately a quarter of the water used by industry, being in many countries (especially island nations) where the groundwater is the only available source of freshwater. In addition to meeting the needs for drinking water, food production, and industrial use, groundwater plays a key role in environmental balance by sustaining the natural flows of rivers and wetland habitats, particularly during periods of drought.

This section / subsection of BIP-H topic is not intended to give learners all the knowledge and skills required to be a professional hydrogeologist. The following educational and instructional outcomes are intended to ensure all hydrologists have a basic grounding in hydrogeology and groundwater exploration.

<u>Hydrologist shall be able:</u>

- To differentiate principles of surface and groundwater hydrology in diverse scenarios to analyse runoff formation, flow distribution, and water quality.
- To explain the origin and occurrence of groundwater in varied hydrogeological settings, including methods of data acquisition and processing.
- To interpret potentiometric surfaces, water table maps, and timeseries to diagnose groundwater flow systems and identify recharge and/or discharge zones.
- To recognize the suitable groundwater exploration methods for different geological environments.

The following table is intended to help define instructional learning outcomes within modules in hydrogeology and groundwater exploration. It is meant to indicate the level of complexity and the depth of learning needed to acquire the knowledge and skills in this topic that are necessary to become a hydrologist. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the requirements in Hydrogeology and groundwater exploration

Hydrogeology and groundwater exploration	
Principles of groundwater hydrology	Identify origin and occurrence of groundwater Classify geological formations according to their hydrogeological behaviour. Explain groundwater terminology: aquifer, piezometric head, porosity, hydraulic conductivity, transmissivity, storage coefficient, hydraulic gradient, Darcy’s law. Recognize recharge and discharge processes, and groundwater–surface water interactions .
Data acquisition and management	Establish metadata and standard formats for records and sampling (step-by-step procedures).

	Recognize uncertainties associated with measurements. Compare time series to identify inconsistencies. Define when to perform quality and maintenance audits on equipment and data loggers. Generate control products: diagnostic charts, corrected hydrographs, preliminary piezometric maps, and quality assurance and quality control reports (QA/QC reports).
Groundwater exploration	Explain the fundamentals of the surface and subsurface exploration methods (geophysical, geological, hydro chemical, remote sensing) considering different geological environments. Define the types of pumping tests. Illustrate the field procedures for executing a pumping test. Interpret the results of the pumping test.

2.4.4 Hydrological Network Design and Monitoring

Hydrological networks and monitoring systems form the backbone of hydrological science and operational hydrological services. Hydrologists rely on well-designed monitoring networks to obtain timely, accurate, reliable, and representative observations of hydrological variables across space and time. These data underpin hydrological analyses, modelling, forecasting, and decision-making for water resources management, flood and drought risk reduction, climate adaptation, and environmental protection.

The learning outcomes in this topic of BIP-H are not intended to produce specialists in instrumentation engineering or network optimization. Rather, they aim to ensure that all hydrologists understand the purpose, design principles, and operational considerations of hydrological monitoring networks. This grounding enables hydrologists to critically assess data quality and coverage, contribute to network design and modernization, and communicate monitoring needs and limitations effectively to decision-makers and technical partners.

Hydrologist shall be able:

- To identify the purpose of the hydrological network and list key design considerations, for meaningful, accurate and reliable data collection.
- To explain approaches for optimizing the configuration of hydrological monitoring network and suitable instrument and sensor selection to maximize data quality and coverage while minimizing cost and effort.
- To describe the technological development of monitoring instruments, emerging technologies, and other sources of data.

The following table is intended to help define instructional learning outcomes within modules in hydrological network design and monitoring. It is meant to indicate the level of complexity and the depth of learning needed to acquire the knowledge and skills in this topic that are necessary to become a hydrologist. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the requirements in Hydrological Network Design and Monitoring

Hydrometry	
Hydrometric Fundamentals	Define Hydrometers, Hydrographs, and Reference Levels. Outline the components of the hydrological cycle, their terminology, and general approaches relevant to measurement and data analysis.
Liquid Flow Measurements: Methods and Equipment	Explain the principles behind various methods used for liquid flow measurements (e.g., velocity-area,

	dilution, acoustic Doppler current profilers (ADCP)). Apply field procedures to measure velocity using instruments like current meters or floats. Identify the limitations and sources of error in flow measurement instruments and techniques. Apply the velocity-area method for calculating discharge in open and ice-covered channels.
Hydro-topographic Surveys (Bathymetry)	Describe the methods and equipment necessary for conducting hydro-topographic surveys (bathymetry), including sounding instruments. Use position fixing techniques (e.g., GPS, sextant) for accurately locating measurement points in cross-sections.
Gauges and Stations	Outline the principles for selecting appropriate sites for water level gauging stations. List the different types of gauges and recorders used for water level measurement. Explain the accuracy requirements for water level measurement based on monitoring standards. Recall safety procedures necessary when conducting field measurements and maintaining hydrometric stations.

Rating Curves and Data Interpretation	Summarize the relationship between water level (stage) and discharge in a channel cross-section. Construct rating curves using methodologies based on measured water level and discharge estimations. Identify anomalies or inconsistencies in stage-discharge data. Translate raw observation data into standardized records (e.g., daily and monthly summaries, extremes).
Sediment Transport Fundamentals	List the properties and classifications of sediments. Define key concepts related to sediment transport (e.g., bed load, suspended load, wash load). Explain the critical conditions necessary for the initiation of particle movement from the channel bed. Compare the instruments and methods used for sediment sampling (e.g., bottom sampling, suspended load sampling). Apply computational methods to estimate sediment transport series and analyze relations with water discharge.
Hydrological network design and monitoring	

Objectives and principles of network design	Define the purpose of a Hydrological Monitoring Network (flood forecasting, water resource management, early warning system, Drought Monitoring). List key design considerations for hydrological networks, such as spatial coverage, temporal resolution, data accuracy, reliability, redundancy, and long-term sustainability. Determine network density and spatial distribution to ensure representativeness and efficiency. Describe standard criteria and guidelines used in the planning and design of hydrological monitoring networks.
Evaluation of existing network and selection of site	Analyze the coverage, redundancy, and representativeness of existing sites, and propose network expansion, consolidation, or modernization considering optimization and financial sustainability. Describe criteria for relocating or decommissioning stations, and for identifying new priority sites. Explain the selection of appropriate sites for gauging stations, wells, and sensors based on hydrological, geomorphological, and logistical criteria along with cost, accuracy, and coverage.

Characteristics of hydrological-meteorological variables and measurement frequency.	Distinguish between variables such as level, streamflow, sediment, and water quality. Selecting appropriate observation frequency for each variable (e.g. daily water quality parameters or continuous streamflow)
Classification of Instruments	Identify suitable instruments for measuring various parameters. Differentiate among sensor types (e.g., radar, ADCP, pressure transducers) and match instruments to hydrological objectives, site conditions, and monitoring purposes. 1. Choose suitable instruments and technologies (rain gauges, stream gauges, ADCPs, telemetry systems, remote sensing). 2. Develop protocols for installation, calibration, and maintenance of monitoring stations. 3. Apply GIS and remote sensing tools to optimize network design and evaluate spatial coverage. 4. Integrate traditional ground-based networks with modern sensor networks and satellite data. Explain factors influencing instrument and sensor selection, including cost, durability, maintenance needs, data transmission capability, and environmental conditions.

Selection of data transmission system	Compare technologies (e.g. satellite, GSM, radio, internet) and select the most suitable option considering site context, remoteness, cost, and reliability. Describe appropriate approaches for data collection, transmission, and storage systems ensuring quality control and accessibility. Describe approaches to assessing network performance using statistical and hydrological criteria (redundancy, accuracy, and reliability). Explain why networks may need to be adapted over time to reflect changing hydrological conditions, land use, and climate.
Financial considerations	Estimate capital, instrument, operation, and maintenance costs, and discuss trade-offs and cost-benefits between advanced and low-cost technologies. Apply cost-benefit analysis; design networks minimizing costs while maintaining data quality.

2.4.5 Concepts of Modelling

Hydrological watershed modelling enables hydrologists to simulate, predict, and understand water movement and storage processes across catchments, supporting critical applications in flood forecasting, water resources planning, climate change impact analysis, and climate adaptation. This topic establishes the foundational understanding required to select appropriate modelling approaches and interpret model results within operational contexts.

The topic introduces fundamental watershed modelling concepts including model types (conceptual, physical, mathematical), structural components, and basic approaches. Learners develop competence in selecting appropriate hydrological modelling methods, understanding their data requirements and limitations, and applying structured frameworks for model selection and evaluation based on catchment characteristics and application needs.

This topic also introduces river hydraulics allowing the hydrologist to understand and apply the principles for open channel flow modelling in rivers. This allows hydrologists to estimate flow discharge using hydraulic modelling, to analyze types of flow, to analyze and extend water level and discharge relationships, as well as applying procedures to build rating curves.

Hydrologist shall be able:

- To describe the concept of watershed modelling, the approaches, the methods, their limitations, and applications.
- To outline watershed modelling method selection, model development, and evaluation considering data availability and problem statement.
- To apply quantitative methods in hydraulic analyses to estimate streamflow, identify types of flow, examine gauge–discharge relationships, and develop rating curves

The following table is intended to help define instructional learning outcomes within modules in concepts of modelling. It is meant to indicate the level of complexity and the depth of learning needed to acquire the knowledge and skills in this topic that are necessary to become a hydrologist. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the requirements in Concepts of Modelling

Watershed Modelling	
Fundamentals of Watershed Modelling	Recall definitions of hydrological models (conceptual, physical, mathematical) and their purposes in hydrology. Describe basic modeling approaches: lumped versus distributed, event-based versus continuous, black-box versus process-based, etc.

Model Components and Structure	Identify key components of hydrological watershed models: inputs (precipitation, potential evapotranspiration), state variables (soil moisture, groundwater storage), parameters, and outputs (runoff, streamflow), model databases. Explain relationships between model structure, spatial/temporal scales, and hydrological processes represented.
Modelling Methods and Techniques	Describe fundamental hydrological watershed modelling methods: unit hydrograph, rational method, SCS-CN, lumped conceptual models, distributed physics-based models. Recognize the advantages and limitations of various methods used in different catchments.
Model Selection	Describe criteria for watershed model selection based on problem statements, catchment characteristics, data availability, and computational resources. Apply a decision framework to select an appropriate modelling approach for specific hydrological applications..
Model Calibration and Evaluation	Outline procedures for watershed model calibration using observed data. Recall standard model evaluation criteria, both graphical and statistical, and interpret model performance.
Data Requirements and Limitations	Identify minimum data requirements for modeling across spatial scales. Explain the impacts of data quality, quantity, and uncertainty on model reliability and predictive capability.

Modelling Applications	Outline steps in model development workflow: conceptualization, implementation, testing, validation, scenario analysis.
River Hydraulics	
Flow Classification	Explain properties of open channel flow (Froude number, Reynolds number) and describe classification of flows (subcritical, supercritical, critical). Recognize field conditions indicating different flow regimes in natural rivers.
Conservation laws	Recall continuity equation, momentum equation, specific energy concepts. Describe the application of conservation laws to channel transitions and energy principles.
Flow Types and Computation	Identify characteristics of uniform flow, gradually varied flow (GVF), rapidly varied flow (RVF), and water surface profiles. Describe Manning's equation, Chezy equation, and critical flow conditions. Recognize differences between 1D, 2D, and 3D flow modeling approaches.
Rating Curves	Describe stage-discharge relationship and factors affecting rating curve development. Outline procedures for constructing rating curves from field measurements. Identify anomalies, extrapolation methods, and shifting control techniques in rating curves.
Field Measurements	Recall standard instruments (current meters, ADCP, acoustic Doppler) for streamflow measurement.

	Describe field protocols for velocity-area method and stage measurement at gauging stations.
Routing Methods	Describe reservoir routing (level pool routing) and channel routing (Muskingum method, kinematic wave). Identify applications of routing methods for flood forecasting and reservoir operation.
Sediment Transport	Identify basic sediment transport concepts (bed load, suspended load, total load). Describe common sediment transport formulas and their applications. Recognize relationships between sediment transport and streamflow.

2.4.6 Data Processing and Management

Reliable hydrological data underpins all water resources assessment, flood forecasting, drought monitoring, and infrastructure design, making data processing and management a core competence for hydrologists. This topic equips learners with systematic procedures to acquire, quality control, process, store, and disseminate hydrological observations, ensuring data integrity throughout the operational workflow from field collection to decision support.

The topic covers WMO standard and recommended practices of data collection operations, including instrument handling, field protocols, real-time monitoring networks, and metadata management. Learners develop skills in quality control procedures to detect and flag errors, validate datasets through cross-verification, and apply basic computational techniques for data reduction, transformation, and frequency analysis. The topic addresses relational database systems, hydrological information systems, archiving standards, and dissemination protocols to support effective data sharing and operational decision-making.

Hydrologist shall be able:

- To explain procedures for data acquisition, processing, and quality control to ensure reliable hydrological data availability.

- To describe the use of hydrological information systems to acquire, process, quality control, and disseminate data to support decision making.

The following table is intended to help define instructional learning outcomes within modules in data processing and management. It is meant to indicate the level of complexity and the depth of learning needed to acquire the knowledge and skills in this topic that are necessary to become a hydrologist. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the requirements in Data Processing and Management

Data Processing and Management	
Principles and Purpose of Data Collection	Recall the role of accurate data in hydrological analysis, applications, and water resources management. Describe different types of precipitation, streamflow, groundwater, water quality, sediment, and supporting meteorological observations. Explain protocols for data comparability, metadata management, and sharing.
Data Collection Operations	Identify principles of instrument operation (gauges, sensors, data loggers, telemetry). Describe steps for instrument calibration, maintenance, and site metadata management. Outline standard field protocols for systematic and repeatable measurement activities, maintenance, data handling, logging, transmission, and archiving raw data. Summarize the process of real-time automated data acquisition and monitoring network operations.
Quality Control Procedures	Recognize common sources of errors and inconsistency, and apply basic data screening: flagging outliers, missing data, and instrument malfunctions. Plot the values of multiple variables to identify relationships among them, and visualize correlations between stations (e.g., Q-Q plots) and between variables (e.g., precipitation vs. discharge).

	Explain methods for testing homogeneity, consistency, and continuity in data series (trend tests, break detection, cross-verification, correlation variables). State steps for documentation of corrections, flags, and quality assessment.
Data Processing and Validation	Recall standards for data entry, coding standards (e.g., WMO International and Regional Codes and national coding practices). Describe basic computational techniques for data reduction, data summarization, and outlier detection. Summarize data transformation procedures for hydrological modeling (unit conversion, spatial and temporal aggregation/disaggregation). Describe validation routines: cross-checking with supplementary sources (remote sensing, neighboring stations, hydrological models).
Data Storage and Dissemination	Explain the use of relational databases, GIS, and hydrological information systems for storage and retrieval. Explain methods for creating, documenting, and archiving climate/hydrological datasets and metadata. Outline protocols for safe, accessible, and timely dissemination to users, including reporting standards.

2.4.7 Statistical Methods

Statistical analyses are commonly used by hydrologists to perform various tasks, and hydrologists will find themselves drawing upon techniques and approaches in their role for a variety of purposes. They may draw upon techniques to summarize data, interpret data, develop a myriad of products, as well as preforming various value-added analyses that are of importance to society.

The learning outcomes in this section of BIP-H are not intended to give learners all the knowledge and skills required to be a professional statistician. Rather the outcomes are intended to ensure all hydrologists have a basic grounding in the statistical methods so they can understand data and products derived using statistical techniques, and they can communicate these intelligently to customers.

Hydrologists shall be able:

- To perform statistical techniques to summarize, analyze and interpret hydrological data and products, and
- To apply statistical tools to perform frequency analysis, quality control, and forecasting.

The following table is intended to help define instructional learning outcomes within modules in statistical methods. It is meant to indicate the level of complexity and the depth of learning needed to acquire the knowledge and skills in this topic that are necessary to become a hydrologist. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the requirements in Statistical Methods

Statistical Methods	
Probability Theory and Statistical Techniques	Describe the basic concepts of statistics: definitions, population versus samples, types of data and variables (qualitative versus quantitative). Describe and calculate measures of central tendency (mean, median, mode), dispersion (standard deviation, range), skewness, kurtosis, range, quantiles. Describe suitable ways of displaying statistical data and how best to interpret the results. Articulate how statistical methods are used to assess data quality. Describe some commonly used techniques in hydrology such as hypothesis testing, correlation, linear

	regression, outlier detection, and goodness-of-fit tests.
Spatial Analysis	Describe the basic variability of hydrological variables (e.g., one-hour rainfall). Outline the concepts of some commonly used spatial analysis approaches such as Thiesen Polygons and Inverse Distance Weighting (IDW) and why various techniques may be used.
Frequency Analysis	Describe why and how in general frequency analyses are performed on hydrological data Describe the concepts of the return period. Explain some types of distributions commonly used in hydrology and why they are selected for specific applications (e.g., normal, Student's t, binomial, Poisson, lognormal, 3-parameter lognormal, Gumbel, Generalized Extreme Value, Weibull, log Pearson type 3). Describe some methods of estimating parameters of distributions, such as moments, l-moments, maximum likelihood, and graphical fitting. Explain the advantages and disadvantages of various fitting methods. Describe probability plotting formulas and their use in frequency analysis. Apply a few methods to estimate the parameters of some commonly used distributions to estimate the frequency of flooding or n-day low flows, plotting the cumulative distribution function.
Regression Analysis	Apply the concepts of simple linear regression analysis of hydrological

	applications such as rating curve development and the estimation of the T-year flood or n-day low flow.
Regionalization of Hydrological Variables	Describe approaches commonly used such as index flood method and T-year regression. Describe how to identify homogenous regions and the selection process of regional distributions.
Time Series Analysis	Describe stochastic processes and their relevance in hydrology and water resources management. Describe commonly used techniques including pre-whitening, trend detection, stationarity, periodicity and stochastic components of time series, autocorrelation analysis and spectral analysis, ARIMA modelling, and diagnostic checking. Describe the generation of synthetic series and how they are used in hydrological analysis and water resources management.

2.4.8 Introduction to Hydrological Services and Communication

Hydrological Services play a critical role in transforming hydrological data and scientific understanding into information, products, and services that support societal needs. Hydrologists working in operational, advisory, and planning roles must not only understand hydrological processes, but also apply this knowledge within institutional, regulatory, and collaborative frameworks to support water security, disaster risk reduction, environmental management, and sustainable development.

Communication serves as a fundamental pillar of hydrological practice, enabling the translation of complex and uncertain information into actionable knowledge for diverse audiences. It requires the appropriate calibration of technical detail, transparent treatment of uncertainty, and adaptation to specific decision-making contexts and timescales. Effective written and oral communication, grounded in collaboration and openness to feedback, ensures that hydrological insights effectively inform decisions and enhances societal resilience.

The learning outcomes in this section of BIP-H are not intended to train specialists in all aspects of service delivery or policy development. Instead, they aim to ensure that hydrologists have a foundational understanding of the role of Hydrological Services, effective communication practices, and the importance of collaboration and data sharing at national, regional, and global levels. This foundation supports hydrologists in contributing to modern, impact-focused, and user-oriented Hydrological Services.

Hydrologists shall be able:

- To explain the role of Hydrological Services in supporting societal needs
- To define approaches for effective, accurate, and appropriate communication of hydrological information.
- To describe the importance of collaborating and data sharing at national, regional, and global levels in strengthening hydrological service delivery.

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The following table is intended to help define instructional learning outcomes within modules in Hydrological Services and Communication. It is meant to indicate the level of complexity and the depth of learning needed to acquire the knowledge and skills in this topic that are necessary to become a hydrologist. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the requirements in Hydrological Services and Communication

Introduction to Hydrological Services and Communication	
Role of Hydrological Services	Explain the mandate and core functions of National Hydrological Services and related institutions. Describe how hydrological services support water management, disaster risk reduction, climate services, and sustainable development.

	Recognize the role of regional and global initiatives, standards, and partnerships in strengthening hydrological services and data exchange. Describe mechanisms for collaboration and coordination at national and transboundary levels, including collaboration in hydrological monitoring aligned with international standards and agreements.
Integrated Water Resources Management (IWRM)	Explain the objectives and components of IWRM for sustainable water management. Understand river basins as units of planning and management, including transboundary challenges. Interpret water balance, water demand/use, and allocation among stakeholders. Identify major policy frameworks and governance structures related to water resources.
Hydrological Data Provision and Interoperability	Prepare a comprehensive hydrological dataset for use in design studies and project planning. Describe basic concepts of database structures and metadata standards for hydrological data. Organize hydrological datasets into a structured database following metadata documentation protocols. Discuss the significance of international collaboration in hydrological monitoring with international standards and agreements.

	Implement interoperability standards (e.g., data formats, APIs) for sharing hydrological data.
Hydrological Early Warning System	Define key risk-related terms such as threat, vulnerability, exposure, mitigation, and adaptation. Describe the differences between climate variability and climate change and their hydrological impacts. Identify the components and functions of an Early Warning System (EWS) for hydrological hazards. Explain the role of EWS in disaster risk reduction and community resilience. Evaluate communication strategies used in EWS for timely and accurate alerts.
Environmental and Ecosystem Management	Define key terms and principles of ecohydrology. Explain the interactions between ecological processes and the hydrological cycle. Analyze the role of ecohydrology in maintaining ecosystem services. Describe the sources of water quality pressures and associated risks. Recognize the relationship between water quality and water quantity Gain knowledge of the primary sources of water contamination and mitigation. Recognize the relationship between ecosystems and water management to

	assess the potential impacts of human activities and ensure sustainability.
Infrastructure planning and design	Understand the significance of extreme events in sustainable civil infrastructure design and analyze flood and drought scenarios using historical hydrometeorological data to inform resilient design decisions. Produce a hydrological impact assessment for an infrastructure project. Integrate hydrological modeling tools (e.g., HEC-HMS, SWMM, MIKE SHE, MODFLOW, etc.) into planning and design workflows. Identify the key components and standards required for hydrological codes in civil engineering projects.
Communication and Stakeholder Engagement	Identify common hydrological information products (e.g., bulletins, forecasts, warnings, assessments). Apply principles of clear, accurate, and audience-appropriate communication of hydrological information. Interpret and transparently communicate uncertainty and limitations in data and products. Develop professionally structured written documents that effectively communicate scientific or operational information through clear text, tables, figures, captions, forecasts, warnings, and technical reports. Identify key stakeholders (e.g., water managers, emergency services, policymakers, public) and describe how

	their needs shape product design, timing, and communication approaches. Collaborate effectively in team environments and respond constructively to peer or reviewer feedback by planning and implementing appropriate improvements to technical work.

2.5. Selective Specialization

The learning, educational, and instructional outcomes provided within the BIP-H are not intended to train professionals to be specialists in all aspects of operational hydrology. As previously mentioned, the BIP-H, through its prerequisite and mandatory topics, is designed to provide the fundamental knowledge and skills to an entry-level hydrologist upon which they can continue developing the skills and competencies needed for selective specializations. This continuum of prerequisite, mandatory, and specialized knowledge and skill development is shown in Figure 1.6.1 that outlines the hierarchy of education and training for hydrologists. The top-most portion of the pyramid is intended to develop hydrologists so that they may perform tasks in an expert fashion fulfilling their responsibilities or job functions in specialized areas.

Overtime, it is anticipated that competency frameworks will be developed for some of the specialized areas within operational hydrology. As they are developed, they would form part of the Compendium of WMO Competency Frameworks (WMO-No. 1209). As an example, individuals wishing to work in areas such as flash flood forecasting would need to undertake training to obtain job competencies in this specialized area, noting that its competency framework is under development.

As previously mentioned, a survey was circulated to WMO members requesting them to prioritize topics for the development of competency frameworks to support the provision of services in operational hydrology. The top-most priorities were identified as early warnings for riverine, flash, and urban floods. The table below provides a summary of specialized areas. The list is intended to be indicative of the range and type of selective specializations, rather than being exhaustive or limiting. It outlines the variety of potential topics and their relative priority for the development of specializations for hydrologists.

In addition, it is important to emphasize that professional hydrologists are expected throughout their professional careers to continue enhancing their knowledge and skills by participating in continuous development. Such efforts assist hydrologists in maintaining and broadening their skills. This is particularly important when new technologies or methodologies are developed and adapted for operational use or when an individual is endeavouring to become competent in performing new tasks and job functions.

Table. The list is intended to be indicative of the range and type of selective specializations, rather than being exhaustive or limiting.

Early Warnings for Riverine flooding
Early Warnings for Flash floods
Early Warnings for Urban floods
Communication of hydrological warnings, products and information
Integrated Flood Management
Early Warning for Hydrological Drought
Integrated Drought Management
Integrated Water Resources Management
Early Warnings for Dam Break
Early Warnings for Debris Flow/Flooding

3. BASIC INSTRUCTIONAL PACKAGE FOR HYDROLOGICAL TECHNICIANS

This part of the document contains guidance on how to implement the learning outcomes of BIP-HT. These learning outcomes will support the *Technical Regulations* (WMO-No. 49). This section starts with an outline of the aims of BIP-HT and then specifies the learning outcomes associated with foundational topics. The rest of this section deals with the learning outcomes for mandatory general hydrology topics and the underlying knowledge and skills that hydrological technicians can use to develop knowledge and competencies.

The overall aim of BIP-HT provides basic knowledge of hydrological processes, as well as skills related to that knowledge. To satisfy the requirements of BIP-HT, participants must achieve the learning outcomes that cover:

- Basic mathematics, physics, chemistry and computer operations as pre-requisites,
- Introduction to hydrological processes, geography, climatology, meteorology, statistics and instrument installation,
- Basic knowledge of hydrological monitoring and data recording, and primary data processing.

The BIP-HT requirements are intended to provide participants with the knowledge, skills and confidence to carry on developing their expertise and to further specialize.

Individuals wishing to work in specialized areas such as water quality will need to undertake further education and training to obtain specialized job competencies in these areas. In addition, individuals are expected to continue enhancing their knowledge and skills by participating in continuous professional development throughout their careers.

3.1 Interpretation

In this chapter, text enclosed in grey-shaded boxes, like this example, are excerpts proposed for the next edition of the *Technical Regulations* (WMO-No. 49) and will have the regulatory status of standard practices and procedures.

The remainder of this section includes narrative and suggested learning outcomes. The outcomes are intended to guide WMO Members on the implementation of BIP-HT, but do not have regulatory status.

3.2 Overarching learning outcomes

This section describes the key attributes and skills that mark a professional hydrological technician, no matter what role they end up taking on. These overarching learning outcomes are also intended to summarize the overall philosophy of BIP-HT by describing how hydrological technicians think and use the data and tools at their disposal to carry out their professional work.

The outcomes described here are not intended to describe any specific role, nor do they assume the context within which an individual might eventually be employed. The outcomes are not necessarily intended to map directly to modules or units of study. Rather, they should permeate and be used to assess an overall programme of study to ensure that individual units of study contribute to the broader aims of the programme, that is, embedding hydrological thinking and practice and making links between theory, the real hydrological cycle and the provision of scientific and professional services to the benefit of society.

Hydrological Technicians (HTs) shall be able:

- To demonstrate basic knowledge of hydrology and related sciences necessary to perform hydrological monitoring
- To demonstrate the ability to install, operate, and maintain hydrological monitoring instruments and maintain site-instruments using Standard Operating Procedures to ensure reliable and accurate measurements.
- To explain the principles of data quality assurance and derive additional hydrological variables using hydrological observations and appropriate methodologies and techniques.
- To explain clearly and precisely to both technical and non-technical stakeholders, the importance of monitoring and data acquisition procedures.
- To reflect actively on learning and work practices to guide continuous improvement of professional knowledge and competence.

These learning outcomes should be achieved through learning and assessment of the hydrological topics described later in this section supplemented where necessary by the professional learning outcomes and other outcomes as required to meet national needs and supported by the advice on foundation topics also contained in this part of the guidance.

3.3. Prerequisites

3.3.1. Mathematics

For hydrological technicians, mathematics is not just a subject: it is the working language that allows them to transform water-related observations into reliable knowledge and practical solutions. Mathematics gives technicians the ability to convert raw field data (rainfall, river levels, groundwater depth) into meaningful quantities that are the basis for use in water management, disaster risk reduction, and in support of policy development, and for other purposes such as sustainable development.

The learning outcomes in this section of BIP HT are not intended to give learners all the knowledge and skills required in mathematics to be a professional in this science. Rather they are intended to ensure all hydrological technicians have a common basic grounding in this subject so they can confidently apply mathematical principles to hydrological measurements, interpret data with accuracy, support modelling and forecasting processes, and communicate quantitative results in a clear and consistent manner across the profession.

Hydrological Technicians shall be able to:

- Compute basic algebraic operations to solve basic hydrological equations.
- Use geometry and trigonometry to calculate watershed areas, river cross-sections, and slope gradients.
- Interpret and construct graphs to analyse hydrological data reliability.
- Communicate quantitative results clearly and consistently in reports, maps, and technical documents.

The following table is intended to help define instructional learning outcomes within modules in mathematics. It is meant to indicate the level of complexity and the depth of learning needed to acquire the prerequisite knowledge and skills in mathematics needed to pursue studies to become a hydrological technician. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the prerequisites of the modules in mathematics

Mathematics

Arithmetic	Perform basic mathematical operations such as addition, subtraction, multiplication, and division, as well as exponentiation, logarithms, and root extraction. Apply unit conversions and dimensional analysis or convert units consistently.
Algebra	Manipulate and solve basic algebraic equations, like discharge and rainfall intensity calculations.
Geometry	Compute the areas and volumes of fundamental geometric shapes. Understand and apply the concepts of coordinate systems, including Cartesian and polar, perform conversions between these systems, and use them in graphs and basic analytic geometry applications in hydrology.
Trigonometry	Define sine, cosine, and tangent, describe their relationships with their inverse functions and manipulate basic trigonometric equations. Calculate slopes, gradients, and perform basic cross-sectional analyses of rivers and channels.
Basic Statistics	Recognize ratios, proportions, and scaling. Summarize data using measures of central tendency like mean, median, and mode. Apply measures of data dispersion or variability, such as standard deviation

	and interquartile ranges, to assess and represent the spread of the data. Understand the concepts of uncertainty, bias, and error margins in data collection.

3.3.2. Physics

An operational hydrological technician should have the knowledge of applied physics enabling them to understand, measure, and interpret hydrological processes. The focus is on mechanics, fluid dynamics, and energy principles directly tied to fieldwork (including equipment use), monitoring, and data interpretation.

Hydrological Technicians shall be able to:

- Demonstrate the basic knowledge of physics required to successfully complete the technical components of BIP-HT.
- Understand the physical principles behind instruments and measurements used in hydrology, based on fundamental concepts of mechanics, thermodynamics, and electricity.
- Apply simple physical laws to interpret hydrological data and support field operations.

The following table is intended to help define instructional learning outcomes within modules in physics. It is meant to indicate the level of complexity and the depth of learning needed to acquire the prerequisite knowledge and skills in physics needed to pursue studies to become a hydrological technician. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the prerequisites of the modules in physics

Physics	
Basic Mechanics	Explain force, motion, and equilibrium in simple terms; recognize how these principles apply to water movement and flow measurement.

Fluid Mechanics	Describe hydrostatic pressure and continuity principle; recognize laminar versus turbulent flow and their implications for discharge measurement.
Work, Energy, and Power	Explain basic concepts of energy and power; recognize their role in pumping and water transfer systems.
Temperature and Heat	Identify temperature, heat transfer (conduction, convection, radiation), and their role in evaporation and condensation.
Phases of Water	Recognize phase changes (solid, liquid, gas) and their importance for hydrological processes like evaporation and snowmelt.
Basic Thermodynamics	Outline simple gas laws and energy conservation in relation to atmospheric processes affecting hydrology.
Waves and Oscillations	Recognize basic wave properties and examples relevant to hydrology (surface waves, tides).
Electromagnetic Radiation	Explain why solar radiation matters for evaporation and climate; recognize reflection and absorption by water and soil.
Electricity and Field Instruments	Describe basic electrical concepts (current, voltage, resistance) for safe operation of sensors and data loggers; recognize electromagnetic induction in field equipment.

3.3.3. Basic Computer Operations

Basic computer skills enable hydrological technicians to maintain accurate field records, communicate observations effectively, and handle essential data management tasks required for reliable hydrological monitoring and reporting. This prerequisite topic provides foundational knowledge in operating computers for daily technical work, ensuring data integrity from field collection through office processing and stakeholder communication in operational hydrology settings.

The topic covers computer fundamentals including hardware recognition and the critical role of computing in hydrological workflows, basic operating system functions for file management and data storage, standard software applications for creating reports and performing simple calculations on gauge readings, and internet tools for accessing data portals, sharing observations via email, and using cloud storage for collaborative data handling.

Hydrological Technicians shall be able to:

- Recognize the role of computers in hydrological record keeping, communication, and basic data handling.
- Demonstrate basic operation of computer hardware, software, and file management for technical hydrological tasks.
- Apply standard office software and internet tools for data entry, sharing, and simple reporting in hydrological work.

The following table is intended to help define instructional learning outcomes within modules in basic computer operations. It is meant to indicate the level of complexity and the depth of learning needed to acquire the prerequisite knowledge and skills in basic computer operations needed to pursue studies to become a hydrological technician. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the prerequisites of the modules in basic computer operations

Basic computer operations	
Computer Fundamentals	Explain the importance of computers for hydrological record keeping, communication, and basic data management. Recognize common hardware components (CPU, monitor, keyboard, mouse, USB drives) and their functions in field and office use.
Operating Systems and File Management	Demonstrate familiarity with basic computer operations such as starting up/shutting down a PC, opening/saving files, creating/navigating folders, and recognizing data types (text, numbers, tables).

	Recall basic file operations (copy, rename, delete) and safe shutdown procedures for preserving hydrological records.
Standard Software Applications	Recall basic functions of word processors (typing reports, formatting tables, saving as PDF) and spreadsheets (data entry, simple sums, sorting rainfall records). Demonstrate creating simple tables for gauge readings and basic calculations for daily rainfall totals.
Internet and Communication	Recognize use of web browsers for accessing weather data portals and email for sending hydrological reports. Demonstrate uploading files to cloud storage and attaching rainfall/streamflow data to emails.

3.4 Mandatory topics

3.4.1 Introduction to hydrological processes

Understanding hydrological processes equips hydrological technicians with essential knowledge to monitor water movement, maintain observation networks, and interpret field measurements accurately in operational settings. This topic establishes the practical understanding required for collecting reliable data on precipitation, streamflow, evaporation, and groundwater, supporting catchment management, flood warning systems, and water resources monitoring.

The topic covers the basic components and pathways of the hydrological cycle at catchment scale, including precipitation partitioning, runoff generation mechanisms, and interactions between atmospheric water, surface water, soil moisture, and groundwater storages. Learners develop skills in recognizing topographic and land cover influences on hydrological responses, identifying standard instrumentation for monitoring key processes, and applying basic data processing procedures including data recording and simple statistical summarization of hydrometeorological records.

Hydrological Technicians shall be able to:

- To describe the hydrological cycle, its components and their interaction at the catchment scale

- To outline the natural and anthropogenic factors influencing hydrological behaviour at the catchment scale.

The following table is intended to help define instructional learning outcomes within modules in introduction to hydrological processes. It is meant to indicate the level of complexity and the depth of learning needed to acquire the knowledge and skills in this topic that are necessary to become a hydrological technician. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the requirements in Introduction to hydrological processes

Introduction to hydrological processes	
Hydrological Cycle	Recall basic components of the hydrological cycle: precipitation, evaporation, transpiration, infiltration, runoff, groundwater flow, and storage. Describe water movement pathways from atmosphere to land surface and return, using correct technical terminology. Identify major storages (surface water, soil moisture, groundwater) at the catchment scale.
Catchment Scale Processes	Explain precipitation distribution into interception, infiltration, evaporation, and runoff at catchment level. Describe sequence of surface runoff generation, channel routing, and baseflow contribution to streamflow. Recognize temporal sequence of processes during rainfall events (ponding, infiltration, saturation, runoff initiation). Identify topographic (slope, shape, relief) and land cover factors affecting hydrological responses of catchment.
Instrumentations for Hydrological Processes	Identify common instruments for measuring precipitation (rain gauges), streamflow (staff gauges, current meters), evaporation (pans), and groundwater levels (piezometers).

	Recognize standard guidelines for obtaining reliable hydrological measurements. Recall data recording procedures as per guidelines.
Processing and Analysis of Hydrometeorological Data	Describe basic steps for processing collected data (gap filling, consistency checks). Outline basic hydrographs and rainfall time series to identify storm events and resulting flow characteristics. Describe simple statistics from hydrometeorological records (daily totals, monthly averages, maximums). Recognize common data quality issues (outliers, instrument drift, missing records) in hydrological datasets.

3.4.2 Introduction to statistical methods

Statistical analyses are commonly used by hydrological technicians to perform various tasks, and they will find themselves drawing upon techniques and approaches in their role for a variety of purposes. They may draw upon techniques to summarize data, interpret data, develop products, as well as preforming various value-added analyses that are of importance to society.

The learning outcomes in this section of BIP-HT are not intended to give learners all the knowledge and skills required to be professional statisticians. Rather the outcomes are intended to ensure all hydrological technicians have a basic grounding in the statistical methods so they can understand data and products derived using statistical techniques, and they can communicate these intelligently to customers.

Hydrological technicians shall be able:

- To compute basic statistics of hydrological variables, and
- To interpret simple statistical measures in assessing data quality, outliers, and rating curves.

- Describe basic statistical measures used to summarize hydrological data and forecast products and their uncertainty
- Describe some statistical tools commonly used in hydrology for performing frequency analysis, regionalizing variables (e.g., T-year flood or drought), and forecasting (e.g., monthly to seasonal)

The following table is intended to help define instructional learning outcomes within modules in introduction to statistical methods. It is meant to indicate the level of complexity and the depth of learning needed to acquire the knowledge and skills in this topic that are necessary to become a hydrological technician. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the requirements in Introduction to statistical methods

Introduction to Statistical Methods	
Characteristics of Distributions	Understand basic concepts of statistics: definitions, population vs. samples, types of data, and variables (qualitative versus quantitative). Describe and calculate measures of central tendency (mean, median, mode), dispersion (standard deviation, range), skewness, kurtosis, range, quantiles. Describe suitable ways of displaying statistical data and how best to interpret the results.
Frequency Analysis	Describe why and how, in general, frequency analyses are performed on hydrological data. Describe the concept of the return period. Explain some types of distributions commonly used in hydrology and why

	they are selected for specific applications (e.g., Student's t, binomial, Poisson, normal, lognormal, 3-parameter lognormal, Gumbel, Generalized Extreme Value, Weibull, log Pearson type 3).
Probability Theory and Statistical Techniques	Describe the concepts of random variables (discrete and continuous), permutations, combinations, and probability. Describe some commonly used techniques in hydrology such as hypothesis testing, correlation, linear regression, outlier detection, and goodness-of-fit tests. Articulate how statistical methods are used to assess data quality.
Regression Analysis	Describe the application and limitations of linear regression using hydrological data such as for the development of rating curves.

3.4.3. Introduction to geography, climatology and meteorology

Basic knowledge of geography, meteorology, and climatology provides hydrological technicians with the essential foundational knowledge required for taking accurate hydrological observations and performing effective field operations. Geographic and geological characteristics—such as basin features, topography, land use, and soil and rock types—strongly influence how water is stored, flows across the landscape, and infiltrates into the ground. At the same time, lower-atmosphere processes, including precipitation, temperature, wind speed and direction, and cloud formation, directly affect evaporation, runoff generation, river flow, and seasonal water availability.

This foundational knowledge enables hydrological technicians to recognize how geography, weather, and climate interact to shape hydrological responses and to correctly interpret basic meteorological and climatological conditions during data collection. By identifying key landforms, precipitation types, local wind systems, seasonal patterns, snow and ice storage, and the proper use of standard meteorological instruments and station networks, technicians are better equipped to support reliable hydrological measurements, field assessments, and routine hydrological analysis across different environments and seasons.

The learning outcomes in this section of BIP-HT are not intended to train and produce professional geographers, climatologists or meteorologists. Rather, they aim to ensure that hydrological technicians possess a practical working knowledge of core geographic, meteorological, and climatological concepts necessary to support accurate data collection, field operations, and hydrological monitoring.

Hydrological Technicians shall be able:

- To explain fundamental concepts of geography, weather, and climate pertaining to hydrology.
- To recognize key aspects of geography, weather, and climate and their influence on hydrological response.

The following table is intended to help define instructional learning outcomes within modules in introduction to geography, climatology and meteorology. It is meant to indicate the level of complexity and the depth of learning needed to acquire the knowledge and skills in this topic that are necessary to become a hydrological technician. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the requirements in Introduction to geography, climatology and meteorology

Introduction to geography, climatology and meteorology	
Basic geography and geology	Describe topographical features and the location of stations. Describe basin and local terrain, land use and geological features.
Lower Atmosphere and Clouds	Identify the lowest layer of the atmosphere (troposphere) and recognize its influence on weather, precipitation, and basic cloud formation.

Weather and Climate Fundamentals	Explain the differences between weather and climate in simple terms and why both matter for water availability.
Precipitation Types	Recognize common types of precipitation (rain, snow) and their relevance to river flow and storage
Meteorological Variables	Identify basic weather elements (temperature, rainfall, wind) and understand their influence on evaporation and runoff.
Local wind systems	Recognize simple local wind systems (sea breeze, land breeze) and their effect on rainfall and evaporation.
Basic meteorology and climatology	Outline key meteorological processes critical for water cycle: evaporation, precipitation processes, radiation, wind, snow and ice, air and soil temperatures, humidity, classification of climate, microclimate. Recognize climate patterns (e.g., wet/dry seasons) and how they affect water availability. Recognize snow and ice as water storage components and their seasonal impact on river flow.
Meteorological instruments	Identify common meteorological instruments (e.g., rain gauge, thermometer, barometer, anemometer) and their use for measuring meteorological variables for use in hydrology. Recognize the importance of networks of meteorological and climatological stations.

3.4.4. Introduction to surveying and map reading

Surveying and map reading are fundamental skills that provide the spatial foundation necessary for accurate hydrological monitoring and field operations.

This section of BIP-HT introduces the basics of measurement, essential surveying tools, map interpretation, coordinate systems, and simple field-recording practices, helping learners build the foundational abilities required for reliable hydrological monitoring.

Hydrological Technicians shall be able:

- To explain basic terminology and principles of measurements, surveying, and map reading.
- To identify basic surveying instruments and methods and their use in hydrological monitoring.

The following table is intended to help define instructional learning outcomes within modules in introduction to surveying and map reading. It is meant to indicate the level of complexity and the depth of learning needed to acquire the knowledge and skills in this topic that are necessary to become a hydrological technician. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the requirements in Introduction to surveying and map reading

Surveying and map reading	
Map Reading Basics	Interpret topographic maps and hydrological charts. Identify symbols, contour lines, and scale.
Coordinate Systems & GPS	Explain the concept of geographical coordinates (latitude, longitude, altitude). Use a handheld GPS to obtain point coordinates and elevation.

	Create concise schematic diagrams to represent specific locations or reference points, intended to facilitate spatial orientation and provide precise directional guidance for identifying a designated site.
Basic Field Measurement and Data Recording	Measure short distances using a measuring tape or rangefinder. Describe the concept of elevation and slope. Use simple leveling tools and surveying techniques (e.g., staff and level bubble, stadia technique) to check relative heights. Determine cardinal directions using a compass. Understand bearing and azimuth for site orientation. Record coordinates, distances, and elevations in standard field forms. Ensure clarity and accuracy in field notes. Develop schematic diagrams to illustrate specific conditions at hydrological monitoring sites, as well as the spatial arrangement of measurement locations and associated equipment.

3.4.5. Introduction to metrology, instrumentation and instrument shelters

Hydrological instruments are critical measurement tools used by hydrologic technicians. An understanding of metrology, the types of instruments used, and the shelters used to house instruments are fundamental to the hydrological measurement tasks of hydrologic technicians. This section introduces: basic metrology principles that inform the foundation for instrument selection, instrument calibration, and site selection, an overview of instruments used in hydrologic data collection, and an introduction to instrument shelters.

A basic introduction to metrology, the study of how instruments, measurement methods, and measurement conditions affect the quality (or accuracy) of measurements is addressed in the instructional outcomes. Hydrological technicians having a basic knowledge of metrology and instrumentation are better able to understand the reasons behind measurement methods, instrument selection, and instrument calibration.

The types of instruments used in hydrology are briefly introduced as well as hydrologic shelters used to house instruments at a measurement site. Instruments used to measure physical parameters are emphasized. A small section on water-quality sensors is included. It is recommended that temperature sensors always be introduced regardless of whether an NHS collects water-quality data because of their importance to many instruments measuring correctly. The introduction of instrument shelters focuses on shelters used to house instruments that automatically collect and transmit data. It includes sections on basic circuits, remote power, and data telemetry.

Hydrological technicians shall be able:

- To describe basic concepts of metrology and the importance of measurements in hydrological monitoring, including various influential factors.
- To identify common sensors and instruments for hydrological purposes.
- Describe general procedures and good practices for sensors and instrument installation and their applications.
- Describe basic electrical circuits, batteries, and grounding used in hydrological instrument shelters.
- Describe typical structures used to house hydrological equipment and instruments.
- Identify and describe various systems used to power remote instrumentation and understand how to operate those systems.
- Identify data telemetry systems used to transmit data and explain their use.

The following table is intended to help define instructional learning outcomes within modules in introduction to metrology, instrumentation, and instrument shelters. It is meant to indicate the level of complexity and the depth of learning needed to acquire the knowledge and skills in this topic that are necessary to become a hydrological technician. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the requirements in Introduction to metrology, instrumentation and instrument shelters

Introduction to Metrology

Definition of units of measurements	Describe systems of units, metric and country units (such as United States customary units). Apply unit conversions with emphasis on length, velocity, area, and flux unit conversions.
Traceability of measurements	Explain traceability of instruments and measurements to national standards. Understand calibration standards, including accuracy of those standards. Describe processes for instrument calibration: how often with traceable standards and the use of certified standards and testing laboratories.
Measurement uncertainty	Describe systematic and random measurement errors. Articulate how systematic and random measurement errors relate to instrument specifications and measurement conditions. Demonstrate how to compute combined uncertainty for a simple measurement such as water level or temperature.
Introduction to Instrumentation	
Water level instruments	Identify and describe the various systems used to measure water levels. Describe the strengths and weaknesses of the various systems and when/where to use those systems and instruments.
Water Flow instruments	Identify and describe the various flumes and other methods used to measure flow.

	Describe the strengths and weaknesses of the methods and when/where to use those methods and instruments.
Water velocity instruments	Identify and describe the various water velocity instruments and methods used to measure water velocity. Describe the strengths and weaknesses of each instrument and when/where to use those instruments.
Water quality instruments	Identify and describe the various sensors and instruments that measure temperature. Describe the other main water-quality parameters measured. Describe the methods and/or instruments used to make those measurements.
Introduction to Hydrological Stations for Data Collection	
Basic electronics for instrument shelters	Outline the basic principles of electronics for direct current (DC) equipment. Illustrate simple DC circuits similar to those used in shelters and how to use a digital multimeter. Describe the use and selection of batteries, fuses, voltage regulators, and solar panels used in instrument shelters. Describe the purpose of grounding of equipment and how to assess its adequacy.
Instrument shelters	Identify the types of shelters used.

	Outline the typical equipment installed in shelters. Explain how shelters and instruments are tied into the local vertical datum.
Data collection platforms	Describe how to connect and program instruments and telemetry systems to a data collection platform.
Telemetry systems	Explain the use of satellite and cellular telemetry systems and their respective strengths and weaknesses. Illustrate how to point transmitters/receiver antennas to satellites and the adequacy of cellular coverage.

3.4.6. Hydrological monitoring

Hydrological observing stations provide data to permit the assessment, to an accuracy consistent with its purpose, of the elements of the hydrological cycle and other hydrological characteristics of any region. Hydrological observations include a variety of elements, some of which include water level, discharge, precipitation, temperature, sediment, water quality, soil moisture, and snow and ice characteristics. The ability to collect, process, and use hydrological observations is a core competency for Hydrological Technicians engaged in operational hydrology. Accurate measurement of select elements is essential for water resources planning, flood forecasting, infrastructure design, and environmental management. The instructional outcomes under this topic are designed to equip hydrological technicians with a clear understanding of the principles, parameters, and practical methods involved in hydrological observations. By mastering these outcomes, technicians develop the ability to operate hydrological observation stations, and measure key hydrological parameters using standard instruments and procedures. Emphasis on standard practices, data accuracy, and safety ensures that observations are consistent, reliable, and compliant with established guidelines.

Accurate measurement is essential in hydrological work. Hydrological Technicians must understand both the principles and the practical methods used to observe hydrological conditions, how different instruments operate, when to use different methods, and their strengths and limits. Good calibration, maintenance, and error control are necessary to ensure reliable data. Knowledge of classical and modern techniques and procedures helps produce high-quality data for monitoring, forecasting, and water-resource management.

The instructional outcomes under the topic of measuring techniques are indicated only for a few elements. Development of instructional outcomes at the regional, national, and local levels can focus on hydrological elements of importance, as per their specific requirements.

Instrument maintenance is a critical function for Hydrological Technicians, as the accuracy, continuity, and reliability of hydrological observations depend directly on the condition and performance of field instruments. In operational hydrology, poorly maintained instruments can lead to data gaps, erroneous measurements, and unsafe working conditions, ultimately affecting water resources assessment, flood forecasting, and decision-making. The instructional outcomes under this topic are designed to develop the hydrological technician's competence in preventive, routine, and corrective maintenance of a wide range of hydrological instruments, including hydrometric and automatic weather stations and data loggers. These outcomes emphasize systematic care, correct installation, calibration, troubleshooting, and documentation to ensure long-term instrument performance and data quality. Equal importance is given to safety practices while handling electrical and electronic equipment and while working in challenging field environments.

Hydrological technicians shall be able:

- To explain the importance, principles, and purposes of hydrological monitoring, including key variables, for effective water resources assessment and management.
- To use standard guidelines and protocols to collect, process, and verify hydrological data, including basic error detection and correction, to ensure accuracy and reliability of observations.
- To identify and compare instruments and methods used for measuring hydrological parameters and assess their suitability for different field conditions by evaluating advantages and limitations.
- To select and apply appropriate measurement techniques following prescribed procedures and SOPs to obtain representative, accurate, and consistent hydrological data.
- To ensure safe, standards-compliant instrument operation by maintaining correct installation conditions, recognizing common faults and safety hazards, in line with technical and safety guidelines.
- To perform preventive, routine, and corrective maintenance of hydrological instruments, including AWS and data loggers, through inspection, cleaning, calibration, troubleshooting, and proper documentation.

The following table is intended to help define instructional learning outcomes within modules in hydrological monitoring. It is meant to indicate the level of complexity and the depth of learning needed to acquire the knowledge and skills in this topic that are necessary to become a hydrological technician. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the requirements in Hydrological monitoring

Hydrometry	
Principles of Hydrometry	Define hydrometry and different principles for making observations of parameters for hydrological purposes. Explain the Purpose and scope of hydrological observations. Enumerate components of a hydrological observation station. Recall procedures for site selection and setting up of hydrometric stations.
Hydrological Parameters measured at hydrometric stations	Identify the key hydrological parameters monitored for stream gauging, lake gauging, groundwater observations, soil moisture, precipitation, snow, evaporation, sediment or water quality, etc. Explain the relevance of each hydrological parameter in water resources assessment, flood forecasting, and operational hydrology. Describe the standard principals and methods for measuring each hydrological parameter.

Measuring techniques	
Introduction to Hydrological Measurements	Understand the purpose of hydrological measurements and their importance for flood and drought alerts and water management. Understand key principles for measuring hydrological elements, such as water levels,

	surface flow, precipitation, snow, evaporation, sediment, water quality, etc., and its role in water resource management.
Surface-Water Measurement Methods	Explain traditional methods: staff plate, tape down, stilling-well and float, float sticks, mechanical current meter, volumetric, weirs, flumes. Describe modern methods: pressure transducers, bubbler systems, water-level radar sensors, velocity radar sensors, acoustic doppler current profiler (ADCP), particle image velocimetry (PIV). Understand the limitations of each measurement method and how the limitations affect data quality and accuracy. Enumerate the advantages and disadvantages of each method. Describe the concepts of automated data loggers and telemetry systems for continuous monitoring. Articulate the critical role that consistent logging intervals, proper calibration, and routine maintenance play in ensuring the accuracy, reliability, and validity of field data collected. Identify the appropriate instruments based on site conditions and required accuracy.
Groundwater level measurements	Explain the importance of groundwater level measurements as a part of hydrological observations. Distinguish key groundwater concepts such as water tables, piezometric surfaces, confined and unconfined aquifers, and explain their relevance to groundwater level monitoring. Describe manual groundwater level measurement methods, including steel tapes,

	electric water level indicators, air-line methods, and chalked tape techniques. Describe automatic and continuous groundwater level monitoring methods, such as pressure transducers, data loggers, and telemetry-based observation wells. Outline the limitations and sources of error in groundwater level measurements, including well construction effects, sensor drift, temperature and barometric pressure influences, and human error. Enumerate the advantages and disadvantages of manual versus automated groundwater level measurement techniques. Identify appropriate groundwater level measurement instruments based on aquifer type, depth to water, monitoring objectives, accessibility, and required accuracy. Describe standardized procedures for well identification, reference point establishment, measurement frequency, and data recording, including date, time, and well condition.
Water Quality sampling and parameter measurements	Distinguish key water quality parameters among physical (e.g. temperature, turbidity, conductivity), chemical parameters (e.g., pH, dissolved oxygen, nutrients, etc.), and biological indicators (e.g. coliform and chlorophyll-a). Identify and apply appropriate sampling techniques based on the monitoring objectives, such as grab sampling, composite sampling, or in-situ measurements. Describe accurate measurement of water quality parameters using the right set of instruments and laboratory equipment, recording date, time, location (GPS), weather, and flow conditions.

	Explain the procedure for labeling samples with clarity, and procedures for preservation, transportation, and laboratory analysis to maintain their representativeness and prevent contamination. Outline national and international standards for water sampling (e.g., EPA, WHO) and maintain strong safety awareness.
Sediment sampling and parameter measurements	Describe the two main transport modes: suspended sediment consists of fine particles (silt, clay, and fine sand) and bedload consists of coarser material (sand, gravel). Describe key concepts of sediment transport such as flow velocity, depth, slope, and sediment size and how these impact the selection of the appropriate sampling technique and equipment. Identify different instruments that are used depending on sampling objectives and site conditions, e.g. Depth-Integrating Samplers, Point-Integrating Samplers, and Automatic Samplers. Describe the selection of the appropriate sampler type for the study objective and flow condition. Describe standardized field procedures to ensure representative and repeatable samples. Articulate approaches that should be followed for labelling, preserving, and recording all samples and field data accurately. Describe the importance of regularly calibrating and maintaining sampling equipment and sensors.
Rainfall Measurements	Explain the importance of rainfall measurements in hydrological observations. Distinguish key rainfall characteristics such as rainfall depth, intensity, duration, frequency,

	and spatial variability, and explain their hydrological significance. Describe manual rainfall measurement methods, including non-recording rain gauges, and explain their principles of operation and field use. Describe recording and automatic rainfall measurement instruments, such as tipping bucket gauges, weighing bucket gauges, and optical rain gauges, including their working principles. Understand the limitations and sources of error in rainfall measurement, such as wind effects, evaporation losses, splashing, clogging, and high-intensity rainfall errors, and their impact on data accuracy. Enumerate the advantages and disadvantages of different rainfall measurement methods and instruments. Identify appropriate rainfall measurement instruments based on rainfall intensity, climatic conditions, site exposure, terrain, and required data resolution.
Snow Measurements	Explain the significance of snow measurements in hydrology, including their role in streamflow forecasting, water resources planning, flood prediction, etc. Distinguish key snow parameters such as snow depth, snow density, snow water equivalent (SWE), snow cover extent, and snowmelt rate. Describe manual snow measurement methods, including snow stakes, snow rulers, snow tubes (e.g., Mount Rose sampler), and snow pits, along with their field application. Describe automatic and remote snow measurement techniques, such as snow pillows, snow scales, ultrasonic snow depth sensors, gamma radiation sensors, and satellite-based snow cover observations.

	Understand the limitations and sources of error associated with snow measurements, including wind redistribution, spatial variability, melting effects, and sensor drift, and how these affect data accuracy. Enumerate the advantages and disadvantages of manual, automated, and remote sensing-based snow measurement methods. Identify appropriate snow measurement instruments and methods based on terrain, elevation, climate conditions, accessibility, and required accuracy. Describe standardized field procedures for snow sampling, including site selection, frequency of observations, and safety considerations.
Evaporation Measurements	Explain the role of evaporation measurements in hydrological observations. Describe direct evaporation measurement methods, including Class A pan evaporimeter, floating pans, and lysimeters. Explain the use of meteorological parameters (temperature, humidity, wind speed, solar radiation) in estimating evaporation and evapotranspiration. Understand the limitations and uncertainties associated with evaporation measurements, including pan coefficients, site exposure, and climatic variability.
Emerging and Advanced Measuring Techniques (Introductory)	Recognize emerging hydrological measurement methods and explain their basic operating principles. For example: image-velocimetry, remote sensing (satellite images, radar images, GNSS reflectometry), IoT sensor networks, etc. Identify the main advantages and disadvantages of each emerging hydrological measurement technique, assessing their limitations in terms of cost, spatial and temporal coverage, accuracy, calibration

	requirements, maintenance needs, and the level of user training required. Recognize how varying weather conditions—such as cloud cover, precipitation, or extreme temperatures—can affect the performance and reliability of these technologies.

Instrument Maintenance	
Introduction to Instrument Maintenance	Explain why preventive maintenance is crucial for collecting accurate data. Describe general principles of care (protection from dust, rust, moisture, insects, rodents, etc.). Distinguish between preventive, corrective, and routine maintenance
Maintenance of Hydrological Measurement Instruments: Common Troubleshooting and Repairs	Identify the key components and working principles of commonly used hydrological instruments for rainfall, water level, discharge, water quality, etc. Outline routine preventive maintenance, including cleaning, inspection, lubrication, and minor adjustments, to ensure reliable and continuous instrument operation. Describe how to check and correct instrument installation conditions, such as leveling, alignment, exposure, ventilation, and secure mounting, in accordance with standard guidelines. Describe how to detect and rectify common faults, including blockages, wear and tear, corrosion, leakage, sensor malfunction, and mechanical imbalance. Outline when it is appropriate to escalate major repairs to higher-level technicians or manufacturers. Explain the importance of documenting maintenance activities and observations to

	support long-term instrument performance evaluation.
Automatic Weather Stations and Data Loggers	Describe how to replace batteries, solar panels, and desiccants. Articulate how to clean sensors and check cabling for wear/damage. Describe how to perform sensor calibration using standard references. Articulate how to reset or troubleshoot simple software errors in data loggers.
Calibration Procedures	Explain the importance of calibration in ensuring data reliability. Explain the importance of using standard reference instruments or calibration kits. Describe how to Document calibration details (date, reference used, error margin). Explain the importance of scheduling and following calibration intervals per guidelines.
Safety in Instrument maintenance	Identify potential safety hazards associated with instrument maintenance activities. Describe safety procedures while handling electrical/electronic instruments. Demonstrate safe procedures for working in field conditions, such as near flowing water, during adverse weather

3.4.7. Data recording and primary processing

Data recording and primary processing form the foundation of reliable data analysis and decision-making. This topic introduces learners to the essential distinctions between raw data, processed data, and metadata, along with an understanding of commonly used data formats in scientific and technical applications. It further explains the systematic procedures involved in accurate data recording, proper documentation through metadata, and the application of quality control measures to ensure data integrity. Emphasis is also placed on primary data processing techniques that transform raw observations into usable, consistent, and meaningful datasets suitable for analysis, interpretation, and long-term use.

Hydrological Technicians shall be able:

- To differentiate between raw data, processed data, metadata, and common data formats.
- To describe the procedures for metadata and data recording, quality control, and processing.

The following table is intended to help define instructional learning outcomes within modules in data recording and primary processing. It is meant to indicate the level of complexity and the depth of learning needed to acquire the knowledge and skills in this topic that are necessary to become a hydrological technician. These learning outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the requirements in Data recording and primary processing

Data recording and primary processing	
Introduction to Data Storage concepts	Describe standard units, time steps, and file formats commonly used in hydrological data storage systems. Distinguish between manual, automatic, and digital data formats. Differentiate between raw data, processed data, and metadata Explain the characteristics of raw data (sensor output, manual logs, and unedited field values). Give examples of processed data (corrected, gap-filled, aggregated datasets). Elaborate the importance of metadata in hydrological monitoring.

	Identify types of metadata: Station metadata (location, elevation, site description), Instrument metadata (model, calibration history, accuracy), Classify data collection metadata (sampling interval, method), Data processing metadata (QC procedures, algorithms used). Enumerate various media for data storage like cloud, desktop, CD/ DVD, pen drive, etc.
Data Entry	Outline standard field forms and digital data entry tools. ; Describe practical data entry software/ interfaces. Outline various forms/ formats of data entry. Identify common Data Formats in Hydrology such as text-based, structured, time-series database formats, binary and proprietary logger formats, as well as the advantages and limitations of each format. Describe the importance and use of protocols for data entry.
Primary data validation	Describe procedures for primary validation of data entered (graphical/ Tabular) (outliers' identification) including detecting anomalies or inconsistencies in data. Describe corrective actions to be taken (such as taking of re-measurements) for identified anomalies and inconsistencies.
Data retrieval and report generation	Demonstrate the safe retrieval of data from field instruments, including manual readings and downloads from data loggers.

	Demonstrate the retrieval of historical datasets from a database using simple queries (location, period, or parameter). Illustrate the use of data backup/copy/extraction techniques. Demonstrate the generation of daily, monthly, and yearly reports.
Data security	Describe what constitutes sensitive data. Describe data security and access control guidelines to protect sensitive information. Describe the importance of procedures for making regular data backups to prevent data loss. Describe the archiving of historical data systematically for long-term preservation.

3.4.8 Professional Skills

The section outlines instructional outcomes to support the achievement of several of the overarching outcomes and thus provide the fundamental professional skills that are needed at the outset of a hydrological technician’s career. These instructional outcomes are not intended to be exhaustive or restrictive.

Table. Suggested instructional outcomes to meet the requirements in Communication and teamwork

Communication and teamwork skills	
Written Communication	Use word-processing and other tools to compose and communicate information concisely, accurate and comprehensibly with various audiences
Oral presentation	Explain and communicate information verbally and accurately to different audiences

Teamwork	Collaborate with the team members and share knowledge and work constructively with others

3.5. Selective Specialization

The learning, educational, and instructional outcomes provided within the BIP-HT are not intended to train professionals to be specialists in all aspects of hydrology. As previously mentioned, the BIP-HT, through its prerequisite and mandatory topics, is designed to provide the fundamental knowledge and skills to professional hydrological technicians upon which they can continue developing the skills and competencies needed for selective specializations. This continuum of prerequisite, required, and specialized knowledge and skill development is shown in Figure 1.6.2 that outlines the hierarchy of education and training for hydrologists and hydrological technicians. The top-most portion of the pyramid is intended to develop hydrological technicians so that they may perform tasks in an expert fashion fulfilling their responsibilities or job functions in specialized areas.

Overtime, it is anticipated that competency frameworks will be developed for some of the specialized areas within operational hydrology. As they are developed, they would form part of the Compendium of WMO Competency Frameworks (WMO-No. 1209). As an example, individuals wishing to work in areas such as groundwater monitoring would need to undertake training to obtain job competencies in this specialized area, noting that its competency framework is under development.

A list is provided below that is intended to be indicative of the range and type of selective specializations, rather than being exhaustive or limiting. In addition, it is important to emphasize that professional hydrological technicians are expected throughout their professional careers to continue enhancing their knowledge and skills by participating in continuous development. Such efforts assist hydrological technicians in maintaining and broadening their skills. This is particularly important when new technologies or methodologies are developed and adapted for operational use or when an individual is endeavouring to become competent in performing new tasks and job functions.

Table. Example of selective specification

Hydrometric (Stage/Discharge) Monitoring
Groundwater Monitoring
Water Quality Monitoring

4. REFERENCES (to be developed)