Assessment Guidelines for End-to-End Flood Forecasting and Early Warning Systems

2022 edition

WEATHER CLIMATE WATER

WORLD METEOROLOGICAL ORGANIZATION

WMO-No. 1286

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EDITORIAL NOTE

METEOTERM, the WMO terminology database, may be consulted at https://public.wmo.int/en/meteoterm.

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CONTENTS

FOREWORD

Floods are among the most devastating natural hazards, and account for a large number of disasters reported globally. Over the last few decades, the number of flood events and their impacts have been increasing steadily due to many factors, including an increase in frequency of severe weather events, changes in land use and an increase in population density within flood plains. This makes it critical for countries to have flood forecasting and early warning systems in place to forecast floods with adequate lead times and to support effective response by government agencies and the population in carrying out appropriate risk mitigation measures.

In 2003, WMO established the Flood Forecasting Initiative (FFI) with the objective of improving the capacity of the National Meteorological and Hydrological Services in jointly delivering timely and accurate products and services needed for flood forecasting and warning in collaboration with disaster management authorities who are actively engaged in flood emergency preparedness and response.

One of the key tasks within the framework of the FFI was the development of the present Assessment Guidelines for End-to-End Flood Forecasting and Early Warning Systems (E2E FFEWS) to assist the National Hydrological Services (NHSs) and other related authorities in assessing their flood forecasting capabilities and guide the improvement of their capacities in this area. The assessment guidelines comprise a set of tools that can be used by the NHSs to better analyse the current status of their E2E FFEWS and highlight potential improvements. The prime advantage of the assessment guidelines is that they have been designed to ensure equal applicability by NHSs having different levels of capability and expertise, from developing to the most advanced services. The present guidelines also constitute an important contribution towards the "Early Warning Systems for All" initiative, launched by the United Nations Secretary-General on World Meteorological Day 2022. As Secretary General of the World Meteorological Organization, I am happy to share the assessment guidelines with the global hydrological community and hope that this important tool will be used by countries around the world for the benefit of their people.

Prof. Petteri Taalas
(Secretary-General)

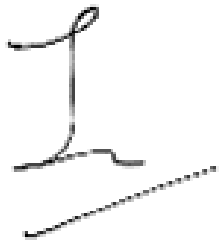
PREFACE

Flood forecasting, warning and informing, underpinned by high-quality hydrological science, monitoring and modelling, are essential components in any multi-hazard early warning system (MHEWS).

End-to-end early warning systems for flood forecasting comprise a 'value cycle' that includes data collection and management, data processing, modelling, integrated approaches to impact- and risk-based forecasts and warnings, and collection of post-event user feedback. Fundamental to this cycle is the 'last mile' dissemination and communication of warnings and advice to the public and decision makers. For a country to build an effective end-to-end early warning system for floods within an overarching MHEWS, it is necessary to identify the strengths and weaknesses of the different components of the value cycle. These guidelines aim to provide a set of useful, practical and flexible tools to support this process.

The development of the Assessment Guidelines for End-to-End Flood Forecasting and Early Warning Systems, initiated under the auspices of the former WMO Commission for Hydrology, began with the selection of a group of experts with a broad range of competencies spanning various aspects of flood monitoring, modelling, forecasting and early warning systems. The assessment guidelines have subsequently been finalized by the Standing Committee on Hydrological Services (SC-HYD), which reports to the Commission for Weather, Climate, Water and Related Environmental Services and Applications (also known as the Services Commission, or SERCOM).

As President of SERCOM, I would like to extend my deep appreciation to the experts who have contributed to the development of these guidelines, namely: Dr Elma Kazazic (Australia) and Dr Yuri Simonov (Russian Federation), who led the drafting group; and Ms Reggina Cabrera (United States of America), Dr Angela Corina (Italy), Mr John Fenwick (New Zealand), Dr Leandro Giordano (Argentina), Dr Mohammed Housseini Ibrahim (Niger), Mr Jeff Perkins (Australia), Dr Paolo Reggiani (Germany), Dr William Scharffenberg (United States of America) and Ms Helvi Shalongo (Namibia). The assessment guidelines underwent a rigorous peer review process, and therefore I would also like to extend my acknowledgements to those who supported this process: Mr Curtis Barrett (United States of America), Dr Yves Bessard (Australia), Mr Martín Sabarots Gerbec (Argentina) and Mr Russell Turner (United Kingdom of Great Britain and Northern Ireland). Finally, I would also like to express my gratitude to the leadership of the SERCOM SC-HYD for their hard work and guidance in completing these important guidelines.



Ian Lisk,
President, Commission for Weather, Climate, Water and
Related Environmental Services and Applications (SERCOM)

1. INTRODUCTION

In June 2019 during its eighteenth session, the World Meteorological Congress reaffirmed its support for the continued implementation of the Flood Forecasting Initiative (FFI) (Resolution 25 (Cg-18)) as one of the major activities which advances fulfilment of the first long-term ambition for operational hydrology – "No one is surprised by a flood" (Resolution 24 (Cg-18)). The FFI supports Members in advancing the use of flood forecasting and early warning systems (EWSs) through specific activities and assistance, where needed. A key activity under the FFI is the development of assessment guidelines to be used by the National Hydrological Service (NHS) or other water authority responsible for issuing flood forecasts and warnings within a country to evaluate its End-to-End Flood Forecasting and Early Warning System (E2E FFEWS). This activity's purpose is to assist Members in improving their understanding of such systems and help them assess their capabilities in this regard. The resulting assessment guidelines, which are contained in the present publication, are also intended to provide the basis for developing the country's National Assessment Report, which should lead to the development of a National Strategic Plan to improve hydrometeorological services. The development of the present assessment guidelines is a continuation of previous actions undertaken by the Commission for Hydrology, which included the establishment of a Task Team on the topic by the Commission for Hydrology at its fifteenth session (December 2016),[1] building on a previous activity on "Improving the Efficiency of Flood Forecasting Services", completed in November 2013 (see report).

It is important to note that not all countries have a separate NHS. This service might be embedded within the National Meteorological and Hydrological Service (NMHS), or there might be another institution that serves the purpose. However, in the guidelines, the term NHS is used to represent this service.

To this end, the Standing Committee on Hydrological Services (under the umbrella of the new WMO Services Commission) has been entrusted with the development of a framework for assessing the capability of NHSs to deliver accurate, timely and spatially adequate flood forecasts that can be interpreted by partners and end users and which support decision-making at various levels. Members of the Standing Committee suggested that such assessment should cover all the processes of an E2E FFEWS chain, from data acquisition to forecast dissemination and communication to end users (Figure 1). They also suggested that it should cover aspects necessary for supporting the operation of an E2E FFEWS, such as infrastructure, coordinating with national disaster management agencies (NDMAs) for awareness, preparation and response planning, and training. The present manuscript provides guidelines for carrying out assessments of national E2E FFEWS and the subsequent documentation of the relevant results.

Figure 1. Hydrological value chain in flood forecasting and early warning

Early warning systems (Bertule, 2017; Ray, 2015) are recognized as an important component of a country's national disaster risk management strategy. The Sendai Framework for Disaster Risk Reduction outlines the following four priority areas for action to prevent new and reduce

[1] In 2016, the Commission for Hydrology approved the following in its workplan: "develop assessment guidelines for NHSs to evaluate their E2E EWS for flood forecasting, furthering the earlier work on 'Efficiency of flood forecasting services' (including testing developed procedures) through the establishment of a Task Team/Working Group, consistent with the FFI-AG Work Plan of 2016–2019" (See Annex 1 to Resolution 10 (CHy-15), focus area: Hydrological Applications, Products and Services, in *Commission for Hydrology (CHy) – Fifteenth Session: Abridged Final Report with Resolutions and Recommendations* (WMO-No. 1184)).

Figure 2. Four elements of end-to-end, people-centric early warning systems based on the Sendai Framework

Source: Multi-hazard Early Warning Systems: A Checklist, WMO, 2017

existing disaster risks: (i) understanding disaster risk; (ii) strengthening disaster risk governance to manage disaster risk; (iii) investing in disaster risk reduction for resilience; and (iv) enhancing disaster preparedness for effective response. The Framework aims to achieve a substantial reduction in disaster risk and loss of lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries. Following the priorities mentioned above, Figure 2 depicts the information to be considered in each case.

Because early warning systems can help prevent loss of life and reduce the health (including mental health), economic and material impacts of hazardous events, including disasters, the Sendai Framework recognizes them as a major element of disaster risk reduction. The benefits of multi-hazard early warning systems are mentioned in one of its targets: "Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030".

An E2E FFEWS is designed to identify a flood hazard with sufficient lead time and should be calibrated to inform effective response by agencies and populations to enable mitigation of inherent risks. Calibration parameters include accuracy, reliability and tolerance for misses and false alarms. The main purpose of such an EWS is to issue warnings when a flood is imminent or already occurring, with an indication of how it will evolve over the immediate future. Therefore, the E2E FFEWS should consider the following interrelated components:

(1) Disaster risk knowledge;

(2) Detection, monitoring, analysis and forecasting of hazards and possible consequences;

(3) Warning dissemination and communication;

(4) Preparedness and response capabilities.

While developing the present assessment guidelines and as part of the work involved in developing a checklist for a robust EWS, two main elements as outlined by the Sendai Framework (see Figure 2) have been addressed: "Detection, monitoring, analysis and forecasting of the hazards and possible consequences" and "Warning dissemination and communication". This checklist, based on the Sendai Framework (UNDRR, 2006), has been released as non-technical reference to ensure that the most important elements of an EWS are covered. Relevant items of the United Nations office for Disaster Risk Reduction (UNDRR) checklist were considered at the beginning of the process of developing the assessment guidelines. Moreover, during the development of the guidelines, several technical details regarding the flood forecasting and early warning process were considered. This enables the assessment guidelines to become broadly applicable at the country and/or basin scale, with the aim of improving national flood forecasting and early warning capabilities.

2. PURPOSE OF THE ASSESSMENT GUIDELINES

As countries can be affected by different types of floods, the E2E FFEWS is a service necessary for almost every NHS. However, depending on the capability of an NHS, different levels of E2E FFEWS can be used, from very basic arrangements to systems with advanced capabilities. The assessment guidelines can be used by those NHSs and/or other national institutions involved in water-related activities that are interested in either setting up a flood forecasting system or upgrading/improving an existing one.

The purpose of the guidelines is to help identify the strengths, weaknesses and gaps in the E2E FFEWS and provide recommendations or guidelines on how to improve current practices. The capacity assessment is a cornerstone for the development of a detailed service plan oriented towards seeking institutional solutions to fill the identified gaps.

The guidelines have been developed in such a way that NHSs with different levels of capacity and expertise (including least developed, developing and most developed) can benefit from their application. They cover all possible issues related to flood forecasting in line with different levels of implementation and requirements – from basic levels of service to state-of-the-art practices and services according to WMO recommendations.

The assessment guidelines include assessment tools which streamline the analysis of existing/needed E2E FFEWS components in terms of readiness and capabilities to generate and issue fit-for-purpose forecasts and warnings concerning riverine floods, flash floods and urban floods, as well as collateral mechanisms (besides precipitation) causing such floods: snowmelt and/or reservoir operations.

3. OVERVIEW OF ASSESSMENT GUIDELINES

An important element to be considered before performing the assessment is the selection of the evaluator(s) composing the assessment team. General recommendations for assigning evaluators are that they should preferably be independent and have relevant experience with the E2E FFEWS process. As the assessment guidelines cover the entire E2E FFEWS chain, it is advisable to select evaluators with expertise in all the different aspects of the E2E FFEWS process. It is recommended that the assessment team be composed of the evaluator(s) plus staff from various relevant stakeholders (such as an NHS, emergency management agency, non-government organization, international organization such as the United Nations) or private consultants. The assessment results can be influenced by the area and level of expertise of the assessment team.

The evaluator(s) should have an understanding of the region being assessed and should ideally be conversant in the language of the country and culturally sensitive. If needed, the WMO Secretariat can be contacted at the address floodmanagement@wmo.int to obtain names of experts who could serve as potential evaluators.

It is important to note that the following assumptions were made when developing the guidelines:

(i) The term NHS is used to represent the service that provides hydrological forecasting. It should be noted that flash flood guidance may frequently be provided by the National Meteorological Service (NMS) with support of the NHS. In such cases, this will be indicated, and the appropriate institution(s) will be named during the assessment.

(ii) Special flooding mechanisms, such as ice-jam flooding, glacial lake outburst floods, dam breaks, and other sources are beyond the level of detail of the present guidelines (readers are advised to refer to the *Guide to Hydrological Practices, Volume II: Management of Water Resources and Application of Hydrological Practices* (WMO-No. 168)). In addition, coastal information is only required to address coastal interaction, to be used as a boundary condition.

It is recommended that the assessment be performed in four chronological phases as shown in Figure 3.

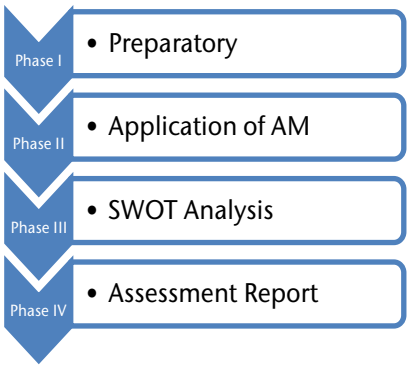


Figure 3. Chronology of an assessment

Note: AM = Assessment Matrix; SWOT = strength, weakness, opportunity and threat.

The **first** or preparatory phase seeks to obtain knowledge of the NHS's operations, identify practices linked to the EWS for flood forecasting, assemble the assessment team and plan the strategy for carrying out the country's assessment. During this phase, it is important to understand the NHS's structure at the national level and its interactions with other services involved in the E2E FFEWS process for flood forecasting (for example: NMSs; NDMAs; Water Authorities; dam, reservoir or facility operators; local governments and other stakeholders). Evaluators should record the responsibilities of each organization in terms of: data and product provision; forecast and warning generation; impact interpretation, communication and dissemination; and emergency response. After mapping this interaction, it is necessary to set up a plan with relevant national organizations to conduct the second phase.

The **second** phase is the application of the Assessment Matrix (AM). The Matrix is a tool developed in the form of an extensive template (matrix) to assist in this process. It is described in more detail in section 4.1. During this phase, the evaluators will carry out technical visits to the identified national services, principal users and any relevant agencies, in order to conduct

interviews. It is critical to ensure that specialized staff from different technical and non-technical areas are contacted directly to allow the evaluators to compile critical information for use in the assessment.

The **third** phase is a Strength, Weakness, Opportunity and Threat (SWOT) Analysis, which is the second tool suggested for this assessment. This tool, which is applied after completing the Assessment Matrix, is composed of two parts: a compilation of the information followed by the analysis itself. The information for the SWOT Analysis is structured to identify the internal and external factors that influence or could influence the flood forecasting practices at the institutional level. Then, the SWOT Analysis is performed to provide insights into FFEWS and highlight capability gaps and opportunities to develop the service where needed.

The outcome of this phase is critical to determine the options for developing and/or improving a flood forecasting service and to identify priority areas to be addressed. In turn, it supports the development of strategies to improve practices related to flood forecasting and it will serve as the basis for creating a National Strategic Plan.

Details about this analysis are presented in section 4.2.

Finally, phase **four** is the completion of the assessment and the preparation of the report. The National Assessment Report should summarize the relevant information gathered, including the most significant results from the application of the assessment tools, and list evaluators' comments and pertinent recommendations. The last part of the report should include priorities for the development/improvement of a National Strategic Plan for establishing capacity to deliver a sustainable flood forecasting service at the national level. Section 5 of the guidelines suggests the key points to be considered and the structure to be followed for drafting an assessment report.

The entire assessment procedure should be undertaken on a relative scale, and the evaluators should refrain from comparing a service with advanced capabilities against a less developed one. The assessment process should provide guidance to the services for sustainably improving practices and activities in support of the E2E FFEWS against existing performance benchmarks towards satisfying users' needs. For countries with a very rudimentary infrastructure, a simplified version of the Assessment Matrix can be employed in place of the complete Matrix at the discretion of the evaluator. It is critical to match the capacity of the NHS to the technology, science and practices recommended.

Further details for each of the phases described above are included in Annex I.

4. ASSESSMENT TOOLS

Two types of tools were designed to conduct the assessment of national capabilities for flood forecasting, namely, the Assessment Matrix and the SWOT Analysis. Their main purpose is to identify elements that might require further development/improvement to enhance the E2E FFEWS. The results from the application of the Matrix and SWOT Analysis should provide information that is critical to define a National Strategic Plan, leading to improved flood forecasting services. It is important to address as many specific topics as possible with the goal of obtaining insight into the current administration and management of the NHS and its development plans, the robustness and flexibility of the flood forecasting service and its capability to meet users' needs.

The tools used in the assessment are described in detail hereunder.

4.1 Assessment Matrix

The Assessment Matrix is the tool (framework) to be used for collecting information assessing the capacity/ability of the flood forecasting and warning service to deliver against and meet the

users' needs while following recommended practices and procedures. A team of experts were tasked with developing a template for the Matrix which is divided into 11 sections. The structure of the Matrix is designed to assist with the collection of information for the assessment.

The Description section of Assessment Matrix includes basic information about the assessment: name of the country, river basin name (for a national assessment this should be left blank), institution(s) involved in the assessment, evaluator(s) name (who is performing the assessment), date of the assessment (or date of last update, if applicable), and project name, if the assessment is a part of any specific project. Because the assessment guidelines can be implemented repeatedly for comparison and for analysing progress with respect to the E2E FFEWS, it is important that the description and the date of the assessment be documented. In addition, this section also contains a list of all the sections of the matrix that should be completed during the assessment, including the auxiliary tables.

Each of the 11 sections of the Assessment Matrix (listed below) covers a specific link in the chain making up the E2E process for flood forecasting (Figure 4).

(i) Institutional;

(ii) Infrastructure;

(iii) Observations and data acquisition;

(iv) Historical and ancillary data;

(v) Data management;

(vi) Meteorological forecast and products;

(vii) Hydrological models, forecasts and platforms;

(viii) Flood forecasting products;

(ix) Dissemination and communication;

(x) Staff capabilities and training;

(xi) Performance and sustainability.

In addition to the 11 sections, there are four auxiliary tables that provide detailed information in support of the assessment. These tables are indicated with the prefix AUX and named as follows:

(i) AUX_Institutional Mapping;

(ii) AUX_Precipitation Stations;

(iii) AUX_Hydrometric Stations;

(iv) AUX_StaffSkills&Training.

Each section of the AM is divided into subsections devoted to specific topics under that section. Provided below is a description of the information that should be included in each of the sections. In addition, a complete summary of the sections along with the relevant subsections is presented in Annex II.

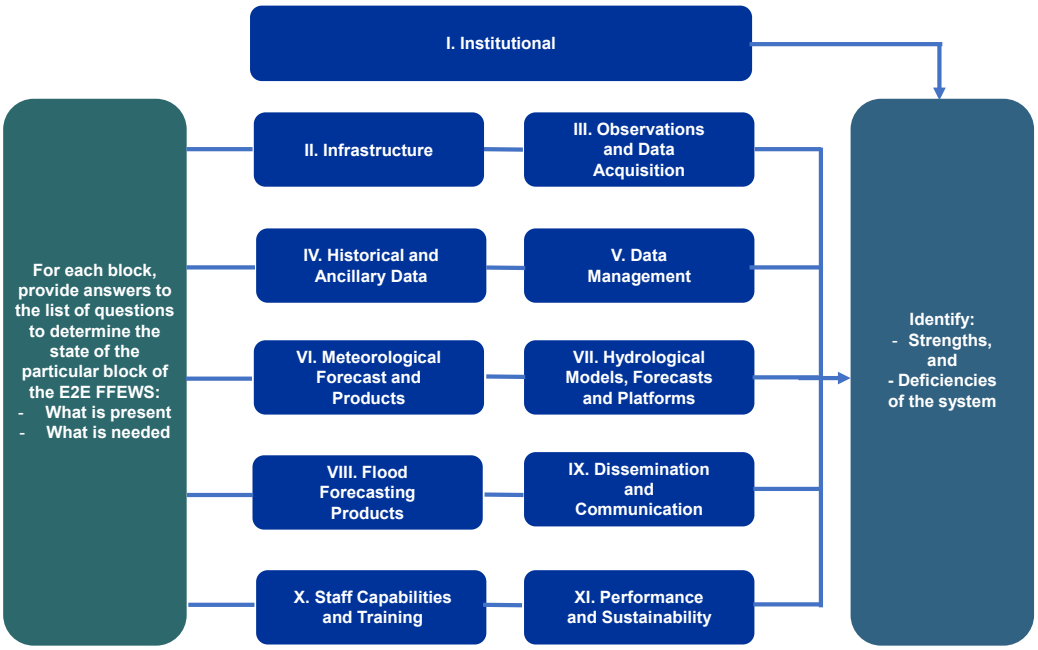


Figure 4. Sections of the Assessment Matrix

(i) Institutional

This section is focused on the institutional setting (for example, whether the NHS is a separate service or is merged with the NMS, and their roles and responsibilities) and seeks to collect general information on the institutional and legal framework of the country in the context of E2E FFEWS, and the national institutional structure for service provision.

(ii) Infrastructure

The "Infrastructure" section is designed to gather information on the physical and technological characteristics (for example, NHS building conditions, internet connection, computers, power supply, backup) that provide the basis for operations.

(iii) Observations and data acquisition

This section focuses on the identification of existing hydrometric stations in the NHS, time series, and processes used for data acquisition. It summarizes the specific features of each station, type of equipment, the existence of rating curves and their status. It also allows evaluators to capture general elements about the station's network and whether it is adequate to meet the requirements of the flood forecasting process and the needs of the service users. In addition, associated meteorological, climatological and coastal information used in hydrological modelling can be collected. This section might require the use of auxiliary tables to collect station information and other pertinent information.

(iv) Historical and ancillary data

This section allows for the collection of historical data (for example, period of record) and additional information useful for selecting practices and procedures that help in improving the performance of an early warning system. It also allows for gathering of information on data availability, quality, and format and whether those are adequate to meet the requirements of the flood forecasting process and the needs of the service users.

(v) Data management

This section supports the identification and documentation of the data management system, its architecture, and the procedures and practices followed by the NHS on aspects concerning data management and data sharing with the main actors linked to the EWS. Information about the database in use is also provided.

(vi) Meteorological forecast and products

Access to meteorological forecasts and specific products is essential for hydrological forecasting. This section compiles relevant information, including details on the availability, frequency, and spatial and temporal resolution of meteorological forecast products that are of relevance in hydrological modelling for flood forecasting.

(vii) Hydrological models, forecasts and platforms

The purpose of this section is to collect information about models, techniques and systems used to generate hydrological forecasts and their capability to deliver against the needs of the service users. It also collects information on the interoperability of the flood forecast system, the ability to use different models, and the ability to visualize results.

(viii) Flood forecasting products

This section captures a description of the concept of operations for the provision of flood forecasting products, the types of products provided (including their format, timeframes etc.) and how easily they are understood and interpreted by users of the service. It is also intended to collect information related to the activities involved in generating flood forecasts and other products to satisfy stakeholders' and users' requirements.

(ix) Dissemination and communication

This section collects information about messages and protocols (such as the Common Alerting Protocol (CAP)) used to communicate warnings to end users and stakeholders and their effectiveness in triggering protective action by agencies and the public. It also covers aspects related to the dissemination of information for preparedness and user response (such as communication system and equipment used, and provision of flash flood alerts and warning services with sufficient lead times). In addition, information regarding impactful (layman's terms) messaging is collected in this section.

(x) Staff capabilities and training

The objective of this section is to assess the current skills and capabilities of the staff in the NHS to deliver the flood warning service. In addition, it is designed to identify recent training received by the staff in line with E2E flood forecasting system activities. The information collected in this section of the assessment helps in determining future training needs.

(xi) Performance and sustainability

The goal of this section is to collect information about aspects that ensure or underpin the robustness of the links of the E2E FFEWS chain. This includes technological, operational, economic and social aspects which are relevant for a sustainable system.

AUX_Institutional Mapping

The information included in this table captures details of the various institutions/agencies that form part of the E2E FFEWS chain with the aim of mapping their mandates, roles and responsibilities, key personnel and the type of services provided.

AUX_Precipitation Stations

This table captures details on the type and location of meteorological equipment (stations) forming part of the E2E FFEWS chain and deployed to collect the precipitation data made available for the institution being evaluated.

AUX_Hydrometric Stations

This table captures details on the type and location of hydrometric equipment (stations) available to the institution/agency that is being evaluated and forming part of the E2E FFEWS chain.

AUX_Staff Skills & Training

The objective of this section is to collect information about the staffing structure, competencies, level of education (qualification) and training requirements of the staff within the institution/agency that is being evaluated.

Once the assessment team is familiar with the Assessment Matrix, and before they decide on how to proceed with the assessment, it is suggested that they conduct staff interviews to assess and fill out the different sections of the Matrix. Selection of the staff to be interviewed should provide a good representation of the different functions of the NHS. For example, this could include staff responsible for: management of the NHS; field observations including data management; forecasting; information technology; telecommunications; administration (including human resources, budget and finance); and communications. It is crucial to interview forecast recipients (end users) and stakeholders, especially national and community disaster management representatives, to understand data, forecast and warning information requirements. It is equally important to address as many topics as possible with the ultimate goal of obtaining an overview of the administration and management of services, development plans, as well as the robustness and flexibility of the service.

The overall structure of the Assessment Matrix template includes options to perform both national and basin-level assessments. This is indicated at the end of the subsection name. The national assessment includes only high-level information, while the basin assessment is more detailed and specific to the type of flood. If an assessment is carried out for several basins, the basin assessment should be completed for each river basin. If several basins are included in the assessment, the tool allows the evaluator to add a different set of questions pertaining to each basin, indicating the basin name before each set.

While the national-level assessment is not specific to any particular flood type, the evaluator(s) should have knowledge regarding the mechanisms causing the different types of floods within the country under assessment. The assessment at the level of a basin/sub-basin will require specific knowledge needed to address issues regarding different types of floods. This should include: observations required; resolution of data (spatial and temporal); data latency; density of the network; types of models to be used in forecasting and how forecasts are prepared – including warnings and how messages/products are constructed; and timeliness for dissemination. In addition, investigating the mechanisms that produce flooding helps the evaluator to determine if the Matrix includes a complete list of necessary items, or if additional data/items are needed.

Each of the 11 sections of the Assessment Matrix is organized as a table (spreadsheet) with subsections (Annex II). Each of the sections is formatted as follows:

1.1 Item

This is a list of all the items considered relevant for assessing the capabilities of the organization relative to a given section.

1.2 Guidance for evaluators

As indicated by the title, this section provides information to guide the evaluator(s) on what elements to consider in determining a score.

1.3 Grading scheme

This includes a dictionary for grading (or description of the grades) as well as the grades themselves. Not every item in the Matrix is graded, as some of them require detailed qualitative descriptions rather than a grading score. For such items, there is no grading description and the section for the grade is shaded black.

1.4 Evaluator comments

This field was designed to record additional information that can be helpful in the overall assessment and may vary from case to case. This is especially useful to collect information for those items that have no grade assigned.

A qualitative grading scheme is adopted for the Matrix. Evaluators need to assign the grade based on the purpose and the nature of the item under consideration. The suggested grading scheme includes six scores from 0 (not existing) to 5 (best practices are followed). To ease the work of the evaluators, scoring descriptions for grades 1, 3 and 5 are given in the survey. The use of intermediate scores (for example, 1.5, 2 and 4) is left to the discretion of the evaluators.

As indicated above, not every item can be scored quantitatively; for some items, only qualitative descriptions can be used. These are entered in the survey under "Evaluator comments".

When possible, staff feedback should be considered to properly assess and complete the grading table.

In those cases where the E2E FFEWS to be assessed is very basic, a simplified version of the Assessment Matrix can be prepared. It is highly recommended that, in order to preserve the overall structure of the Matrix, as described above, the original table structure be kept with regard to format, topics and items.

It is important to notice that these tables are adjustable, depending on the results of Phase 1 (preparatory phase) of the assessment. The assessment team should review the tables in the Matrix and, if they deem it necessary, grey out other options or exclude already greyed-out areas. There is no "one size fits all" solution; instead the team needs to revise and adapt according to the circumstances.

4.2 SWOT Analysis

The goal in completing an assessment of this type is to explore areas in which the E2E FFEWS of a country might be improved to better meet its users' needs. The results of the assessment could be presented by reporting findings and recommendations, giving scores by sections, or giving an overall score. While all these options are encouraged, it is believed that using the SWOT Analysis tool can assist an organization with establishing performance-based objectives and priorities to improve its E2E FFEWS.

The SWOT Analysis is prepared using the results compiled in the Assessment Matrix and based on discussions among the members of the assessment team. The Analysis provides the critical information that is required to define a service improvement plan and ultimately the National Development Plan, leading to improved flood forecasting services.

In order to perform the Analysis, it is necessary to follow a structure. The process consists of two steps, which are described below. Figure 5 contains a schematic representation of the SWOT Analysis that was developed to aid in the management of all the information and facilitate its analysis.

The first step is to divide the findings into two groups: those that are internal to the organization and those that are external to it. They can be further divided into strengths, weaknesses, opportunities and threats. The strengths and weaknesses are internal, while the opportunities and threats are external items. To facilitate the selection of items that belong in each set, a list of criteria is included in Annex III.

It is important to realize that this analysis is based on the criteria for each of the four elements in the SWOT. Evaluators should also consider the following indicators on what to include in each element:

- Strengths: List of current factors within an organization that allow it to deliver a best-practice flood warning service that meets users' needs, and resources identified within an organization for improving its practices in flood forecasting. Example: Installed capacity to carry out rainfall and hydrometric measurements confirmed in a telemetric network distributed in the country with coverage of most of the basins vulnerable to floods.

- Weaknesses: List of factors identified within an organization that create deficiencies or prevent the organization from delivering a best-practice flood warning service that meets users' needs, and lack of resources within an organization for improving its practices in flood forecasting. Example: Financial/economic budget and administrative procedures that support hydrology are inadequate for it to respond as an operational hydrological centre.

- Opportunities: External aspects that impact the organization and its service performance level in a positive manner and could support further development of its service (for example, clear roles at country/basin level to manage flood plain risk and flood emergencies, readiness of WMO and donors to assist). Example: Set up institutional arrangements that include private sector observation networks and maximize the exchange of hydrometeorological information.

- Threats: External threats that impact the organization and its service performance level in a negative manner and could hinder further development of its service (for example, inability to access data collected by other organizations, inadequate budget, budget cuts, irregularities in the supply of electrical energy and telecommunications services).

Annex III provides a compilation of criteria related to strengths, weaknesses, opportunities and threats, and they serve as examples to guide the analysis.

Internal factors: Endogenous issues that are involved in the development of the NHSs	
Strengths (+)	**Weaknesses (–)**
List of current factors within an organization that allow it to deliver a best practice flood warning service that meets users' needs, and resources identified within an organization for improving its practices in flood forecasting.	List of factors identified within an organization that create deficiencies or limit the organization in delivering a best practice flood warning service that meets users' needs, and lack of resources within an organization for improving its practices in flood forecasting.
External factors: Exogenous issues that are involved in the development of the NHSs	
Oportunities (+)	**Threats (–)**
List of identified external aspects that can impact the organization and service performance level in a positive manner and could support further development of its service.	List of identified aspects that could attenuate the strengths of the institution, increase its weaknesses and limit or prevent the realization of opportunities that are captured. These represent a risk to the development of the FF practices and the objectives of the institution.

Figure 5. General structure for findings to be used in the SWOT Analysis

Note: Examples of criteria are presented in Annex III. Note: FF = flood forecasting.

Once the four elements in Figure 5 are populated, it is time to proceed to the analysis itself (step 2), which will identify items that are relevant to improving the flood forecasting service. Again, there is a framework/pathway to follow, and four strategies are defined (Figure 6). A description of what should be included is presented below:

- Strengths–Opportunities: Strengths of the institution that can be used to take advantage or maximize the identified opportunities;
- Weaknesses–Opportunities: Actions that the institution can take to minimize the weaknesses through the identified opportunities;
- Strengths–Threats: Strengths that can be used to minimize the identified threats;
- Weaknesses–Threats: Weaknesses that can be minimized to avoid identified threats.

Internal factors / External factors	Strengths (+)	Weaknesses (–)
	List of current factors within an organization that allow it to deliver a best practice flood warning service that meets users' needs, and resources identified within an organization for improving its practices in flood forecasting.	List of factors identified within an organization that create deficiencies or limit the organization from delivering a best practice flood warning service that meets users' needs, and lack of resources within an organization for improving its practices in flood forecasting.
Opportunities (+)	**Strengths – Opportunities Strategy**	**Weaknesses – Opportunities Strategy**
List of identified external aspects that can impact the organization and service performance level in a positive manner and could support further development of its service.	What **strengths** of the institution can be used to take advantage or maximize the identifed **opportunities**?	What actions can the institution take to minimize the **weaknesses** through the identified **opportunities**?
Threats (–)	**Strengths – Threats Strategy**	**Weaknesses – Threats Strategy**
List of identified aspects that could attenuate the strengths of the institution, increase its weaknesses and limit or prevent the realization of opportunities that are captured. These represent a risk to the development of the FF practices and the objectives of the institution.	How can the **strengths** be used to minimize the identifed **threats**?	How can the **weaknesses** be minimized to avoid the identified **threats**?

Figure 6. General structure for defining the SWOT Analysis

Note: FF = flood forecasting.

The information as presented in Figure 6 facilitates the analysis of the information and creates a strategy for the organization. It will be essential for the National Development Plan. For example, it is possible to discuss how a strength can be used in combination with an opportunity to improve a service, or how an opportunity can be used to address a weakness, and so forth.

5. DEVELOPMENT OF NATIONAL ASSESSMENT REPORT

The National Assessment Report is intended for use by the NHS, with assistance from the assessment team, to generate a forward-looking quality management and service delivery perspective with clear focus on developing/improving flood forecasting services captured by the National Service Development Plan.

The assessment report needs to be written with reference to both the flood forecasting mandate of the NHS and the needs of the users it serves. If these do not align, or are unclear, the assessment team should highlight this as a critical issue to be addressed.

Evaluators need to be sensitive to potential reprisals against staff for any documented inadequacies. The report should emphasize its purpose as a learning and fact-finding exercise, with the goal of enabling resources to be utilized for the benefit of both the agency's users and its staff. Proposing solutions is not the intent of this report; however, it should provide adequate information, including deficiencies reported as constructive criticism, to devise solutions where appropriate. Care must be taken to avoid over-emphasis on benchmarking less developed countries against more developed ones.

It is recommended that the report include at least the following sections:

- An executive summary;
- An introduction covering the background and goals of the assessment;
- Findings on the flood forecasting mandate of the agency and the needs of the communities it serves, including a sub-section on user needs and gaps;
- A list of findings from the Assessment Matrix and the SWOT Analysis;
- Recommendations to support the formulation of National Strategic Plan for the E2E FFEWS;
- Conclusions;
- Recommendations including improvements and prioritization;
- An annex containing the completed Assessment Matrix;
- An annex with notes from field visits and/or any other information acquired during the assessment;
- An annex containing brief minutes of the assessment team's meetings with the involved staff.

If an NHS expresses its intention to improve its E2E FFEWS capabilities by using a pilot basin, the assessment guidelines can help significantly in this regard, as the basin scale of the assessment provides information on the current state of flood forecasting in a river basin(s) in the country.

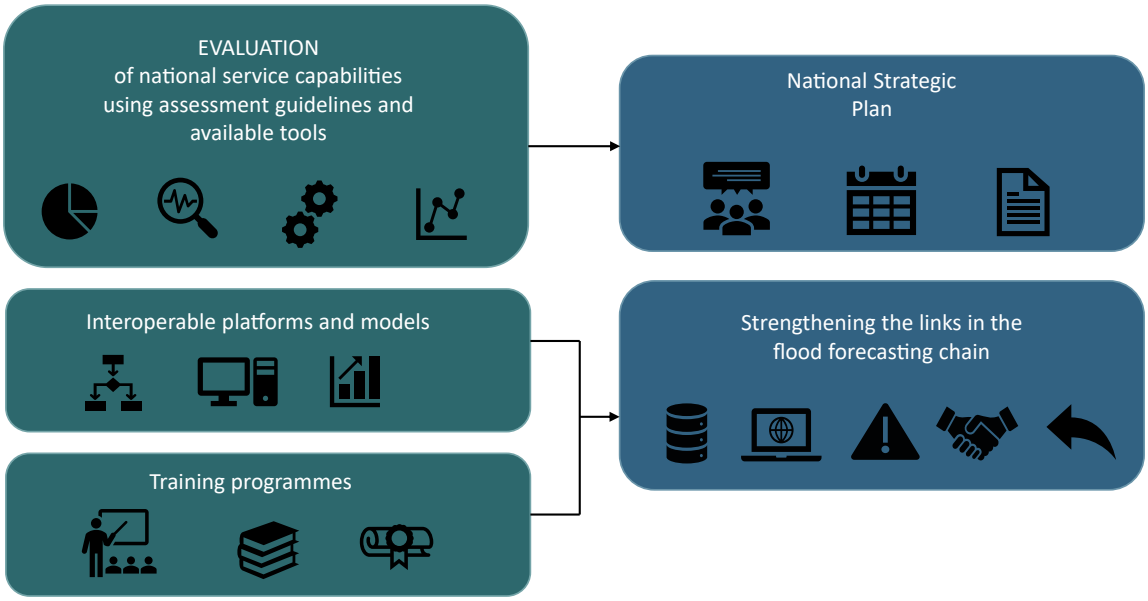


Figure 7. From evaluation to improved services

It is suggested that soon after the assessment report has been delivered, a team from the NHS be established to undertake post-assessment activities. These should focus on actions in response to the results and recommendations of the assessment report. This includes the preparation of a National Strategic Plan. Such a plan would typically include details on how to improve the performance of the service (forecast accuracy, lead time, warning message clarity, etc.) to the levels required by emergency agencies and the community. Specific strategies and objectives could include for instance: enhancing the quality of observed hydrometeorological data, developing the professional abilities of the staff or adopting specific modelling technologies. The plan should contain recommendations for short-term strengthening to fix the biggest gaps that are barriers to acceptable system performance as well as longer-term improvements to build a better, more effective system.

A National Strategic Plan should aim to improve flood forecasting services based on the outcomes of the evaluation performed (Figure 7), which considers the assessment of capabilities versus users' needs. It is recommended that the Plan refer to the resources made available by WMO, including those that are available within the community of practice on E2E EWS for flood forecasting and the capacity development training programmes.

ANNEX I. PHASES IN THE ASSESSMENT IMPLEMENTATION

As described in Section 3, the assessment is performed in four phases: preparatory phase (Phase 1), completion of the Assessment Matrix (Phase 2) and the SWOT Analysis (Phase 3), and preparation of the report (Phase 4). The total duration of the assessment depends on different aspects, including: the characteristics of the NHS under assessment, stakeholders involved at the national level in the E2E FFEWS process, area of the country/basin, flood types and mechanisms involved, number of basins/sub-basins to be covered and number of evaluators. It is estimated that the time required to carry out an assessment can vary between 2 and 2.5 months.

Phase 1 – Preparatory phase

The main activities that occur during the preparatory phase include: (i) documentation of the existing status of the NHS and other stakeholders (including users) involved (institutional mapping), defining national focal points; (ii) review of runoff conditions (both natural and anthropogenic), hydrography, flood types and mechanisms involved, major risk areas and user needs; (iii) definition of the assessment basins and sub-basins (or subdivision of the assessment). It is beneficial, if possible, to enter in the Matrix any information that is available to the evaluators beforehand. This helps in identifying the points that need to be stressed or clarified during the field visit at the next phase.

Additional activities in this phase should include:

- Extensive consultation with the NHS being assessed on insights into the methodology used and the environment under which the specific service is operating.

- Identification of development objectives and assessment of the present status of flood forecasting services and capabilities. This should include the operational and reporting procedures.

- Formal agreement on the overall procedure for the assessment in terms of time, infrastructure to be used, planned field visits and agency interviews, and identifying staff who will take part. Agreement on objectives and additional, service-specific criteria to be used for the assessment.

It is highly recommended that during this phase a schedule for the visit (Phase 2) to the country be formulated and agreed by its NHS.

The estimated duration of Phase 1 is from 7 to 14 working days.

Phase 2 – Completion of the Assessment Matrix

The main tool for assessment – the Matrix – is filled out during a visit to the country. During this phase, all sections of the Assessment Matrix must be discussed and completed appropriately.

As the assessment covers not only the NHS, but other stakeholders as well (NMS, NDMA, other institutions), it is important that meetings with stakeholders or visits to stakeholders' institutions be organized according to the institutional mapping done in Phase 1.

Where possible, field visits should be arranged to obtain an "on-the-ground" verification of the hydrological situation under which a flood forecasting service is operating.

As mentioned above, the Assessment Matrix is completed jointly with the participation of experts from the country during the visit. Final corrections and adjustments (based on additional information) can be added right after the visit. Once the Assessment Matrix has been completed, the information should be reviewed with the participating national agencies, and decisions should be taken regarding whether corrections are needed or additional information is required to complete the Matrix. If additional interviews are needed, phone calls or video meetings can be used.

A total of 10–14 working days is estimated for the completion of Phase 2. This is a preliminary estimate based on similar work and will be refined as more assessments are performed. However, the duration of Phase 2 is dependent on various factors and may vary for each situation.

Phase 3 – Completion of the SWOT Analysis

The SWOT Analysis is done after the field visit, based on the information compiled in the Assessment Matrix. A total of 5–7 working days are required for conducting Phase 3.

Phase 4 – Preparation of the report

Producing a National Assessment Report, which is the main outcome of the assessment, may take anywhere from 30 to 40 days, with an additional 2–3 days for discussion with the NHS on the findings of the assessment. Finalizing the National Assessment Report involves providing key findings and recommendations. This report should support the formulation of a detailed National Strategic Plan to address key weaknesses and identify opportunities for the improvement of flood forecasting services to desired levels.

ANNEX II. ASSESSMENT MATRIX OVERVIEW

The table below shows the sections and subsections of the Assessment Matrix.

Section		*Subsection*	
No.	*Title*	*Item*	*Name*
-	Description	-	General information for assessment
I	Institutional	I.1	National institutional setting of National Hydrological Service
		I.2	Establishing the general context: national or basin
		I.3	Institutional Mapping: national or basin
		I.4	Cooperation and coordination between national institutions: transboundary/national/jurisdiction or basin
		I.5	Institutional agreements on data sharing among different ministries/agencies/data sources: national or basin
II	Infrastructure	II.1	Conditions: national/jurisdiction or basin
		II.2	National technology
III	Observations and data acquisition	III.1	National
		III.2	Riverine flood/flash flood and additional mechanisms: transboundary/national/jurisdiction
		III.3	Additional items for coastal flood assessment: national/basin
		III.4	Additional items for urban flood assessment: basin
IV	Historical and ancillary data	IV.1	National
		IV.2	Riverine flood and flash flood assessment: national/basin
		IV.3	Additional mechanisms: national/basin
		IV.4	Additional items for coastal flood assessment: national/basin
		IV.5	Additional items for urban flood assessment: basin
V	Data management	V.1	Availability and accessibility of data (point and gridded): national/basin
		V.2	Data quality assurance and quality control procedures: national/basin
VI	Meteorological forecast and products	VI.1	National
		VI.2	Meteorological forecast products available for river flood and flash flood modelling: national/basin
		VI.3	Riverine flood forecasting in coastal area: national/basin
VII	Hydrological models, forecasts and platforms	VII.1	National
		VII.2	Hydrological model(s) available for river flood and flash flood forecasting: national/basin
VIII	Flood forecasting products	VIII.1	National
		VIII.2	Basin
IX	Dissemination and communication	IX.1	National/basin
X	Staff capabilities and training	X.1	Staff capabilities and skills: national/jurisdiction
		X.2	Training: national/jurisdiction
XI	Performance and sustainability	XI.1	Fall-back (mirrored) systems and troubleshooting procedures: national/basin
		XI.2	Robustness of the E2E FFEWS: national/basin
		XI.3	Organizational policies on human resources: national/basin

The following AUX tables are included. They are national by nature.

	AUX_Institutional Mapping		Main areas in the E2E FFEWS
	AUX_Precipitation Stations		Precipitation stations
	AUX_Hydrometric Stations		Hydrometric stations
	AUX_StaffSkills&Training		Background and experience for National Hydrological and Meteorological Services

ANNEX III. SUGGESTED LIST OF SWOT CRITERIA

Strengths

- The allocated institutional budget covers the main needs for operational activities (internet connection, maintenance of stations, enough staff, etc.).
- Management is committed to, and proactive in the development and implementation of, institutional plan and projects.
- Headquarters infrastructure allows staff to work in optimal conditions (suitable office equipment and services, security standards, etc.).
- Historical records of hydrological (and/or rainfall) data are available in electronic format at national level.
- An observation network collects and transmits real-time information from rain gauges, automated weather stations and hydrometric stations in catchments vulnerable to flooding.
- The institution can collect data/information from the whole country as well as from the neighbouring countries in the case of transboundary rivers (these data can be used for running models, evaluating potential flood events, developing products, etc.).
- Local network access to real-time numerical weather prediction (NWP) products and information in adequate formats for hydrological models.
- Equipment and tools are available for visualization and data analysis (computers, software, platforms, etc.).
- Adequate bandwidth of internet to communicate big data such as NWP model gridded forecasts (quantitative precipitation forecasts) in real time.
- Numerical or probabilistic hydrological forecast and water-level monitoring operate in real time (24 h per day and 7 days per week) and are connected to a local network.
- Delivered forecast products meet users' needs (communities, partners, industries, etc.) with a clear purpose (nowcasting, seasonal, etc.). Forecasts are sufficiently accurate, provide adequate lead time and are reliable.
- Data and forecast products are available online, allowing users to monitor the development of hydrometeorological events. In addition, the online portal is well-structured, with pedagogical information, and is easy to understand.
- Forecast products are available at various time scales (nowcasting; short-, medium- and long-term; and seasonal) meeting the variable needs of users at these time scales and include all highly vulnerable areas of the country.
- Capacity and technology exist to develop new products for new sectors through existing software or software developed by the institution.
- There is potential to adapt and modify the institutional platform to the requirements of new products.
- Staff are knowledgeable, highly qualified, motivated and experienced. Professionals are willing to transfer knowledge and can seek information from more advanced countries and put it into practice.
- An adequate number of technical and qualified staff is available for the activities of the institution.

- Institutional memory exists and there are operation manuals that describe the concept of operations and are based on WMO standards, practices or lessons are frequently documented, etc.

- Career opportunities and adequate salaries to attract highly qualified personnel are provided.

- Ability to select and recruit qualified staff (the institution is independent in the selection of candidates based on a process where the skills and abilities match the requirements of the position).

- Strong and close relationships with partners (scientific institutes, key public and private sector organizations, community representatives, etc.). This aspect facilitates implementing activities at the national level as well as solving problems and/or developing products according to user needs.

- Staff have access to training plans. This could include improving the understanding of NWP for flash floods, geographical information systems, hydrological models, automatic calibration routines, maintenance of stations, etc. This could be achieved through access to universities, short local courses, international exchange initiatives, etc.

- Existing institutional strategy for 24/7 operational activities (when required).

- Existence of national and/or international projects, and of an agreement for improving practices and/or services.

- There are advances in the development of tools or methods for flood forecasts that are significant and that could be shared with other countries.

- Existing National Strategic Plan to strengthen hydrologic services

- Close coordination and communication with the National Meteorological Service, including sharing data, access to NWP modelling products and interaction and consultation with Meteorological Forecasters – especially for flash flood warnings.

- Ongoing forecast verification programme.

Weaknesses

- Insufficient institutional budget that limits carrying out activities to fulfil the objectives.

- Few initiatives to apply for external financing (this could be linked to the lack of knowledge about national and/or international projects, or to difficulties for developing projects or proposals according to donor requirements).

- Complicated management system, with a convoluted hierarchy and without clear responsibilities, hindering exchange of ideas and implementation of initiatives, and producing duplication of efforts and investments.

- Difficulty hiring competent staff because of bureaucratic procedures or availability of candidates with the appropriate educational qualifications.

- Low salaries that cause difficulty in retaining qualified personnel and affect their motivation to be proactive. Non-competitive salaries compared to the private sector.

- Limited transparency that results in an overlap of investments and in poor project management.

- Limited technical/highly trained staff.

- Trained staff not suited to deal with specific issues (lack of technical or scientific knowledge, limited knowledge of technology such as computers and software, difficulties with management, etc.).
- Inefficient or non-existent management documentation systems, leading to duplication of activities and hindering the staff's autonomy.
- No access to NWP or limited numerical meteorological information.
- No secure electronic backup of historical data or no initiative to carry it out.
- Lack of a data management and control system. Instead, having a fragmented and non-centralized database.
- Inadequate rainfall and hydrometric observation network for flood forecast (limited spatial or temporal coverage, non-real-time transmission, etc.).
- Limited or non-existent budget for the maintenance of the observation network, a factor that affects its durability and reliability.
- Acquisition of equipment not adequate to the country's context (expensive maintenance, inappropriate technology).
- Difficulties sharing data, forecasts and key information among related institutions and partners (at national or transboundary level).
- Limited or lack of adequate work tools or services (institutional computers, internet connection, secure power supply, etc.).
- Lack of hydrological forecasts, limited product elaboration (bulletins, reports of reservoirs, analysis of events) or products and services that do not meet the needs of partners and end users because they are absent, their performance or coverage is insufficient or they are hard to interpret and understand.
- Hydrological forecast products are delivered from external sources that reduce the ability to be proactive and flexible in developing or improving new products.
- Inadequate equipment to undertake research on the development of hydrological products or services.
- Limited procedures to verify current hydrological products (forecasts, warnings, watches), which is a key issue that could help to reduce false alarms.
- Non-existent institutional training plan and limited efforts to seek external collaboration for training or exchange of experiences (either in the public/private sector or academic institutions).
- Headquarters vulnerable to vandalism or located in a flood-prone area.
- Poor communication with regional offices or observers at the national level.

Opportunities

- Existing national laws on risk prevention and response to natural disasters, national/municipal mandates on EWS.
- Strong governance arrangements in place defining roles and responsibilities of the E2E FFEWS partners.
- Good partner relationships based on trust and respect and resulting in a collaborative spirit.

- Comprehensive, consistent and up-to-date mapping of flood risk at national and basin level.
- Availability of national or international programmes for financing activities or services to improve flood forecast practices (acquisition of equipment, specific research, etc.).
- Relationship with WMO or other UN development agencies as a potential source to apply for funding for the development of hydrological services projects.
- Potential inter-institutional collaboration for the development/improvement of the use of NWP for flash floods, hydrological modelling, product elaboration, etc. (at national or international level).
- Possibility to digitize historical data from yearbooks, data bands, etc. through data rescue activity.
- Study plan for an update of the existing observation network (could be done through studies elaborated by the institution's staff or in collaboration with research centres).
- Existence of initiatives to densify the national observation network through mixed networks (public–private networks).
- Agreement with public or private partners (hydroelectric companies, nautical clubs, irrigation companies, etc.) to collect and share information from their rainfall or hydrological stations. (Indicate if they have requested assistance for the installation of stations.)
- Possibility to consult experts for advice on the acquisition of adequate measurement equipment according to the country's context.
- Calibration equipment for stations and other hydrometric equipment. The development of these practices could strengthen alliances with partners and/or generate extra income.
- Recognition of meteorological/hydrological data and information as the main inputs for hydrometeorological risk analysis and design of structures for flood mitigation or water management.
- Growing user demands for hydrometeorological data, products or services, or for specific hydrological information. This opportunity should lead to the development and improvement of services and products according to user needs.
- Growing awareness on the part of the public and decision makers of the country on the impact of weather/climate/water resources and natural risk management on the sustainable development of society.
- Access to new and evolving technology (data storage and transmission, backups, tools for visualization, etc.). This could include a new low-cost technological breakthrough that can be easily applied and scaled. Availability of inexpensive data platforms such as 3D-printed automatic weather stations, rain gauges and stream gauges can significantly increase reliability and sustainability of the observation network.
- Open-source tools for the institution to develop its own platforms, and programming languages to develop work routines that allow it to automate activities and increase productivity.
- Existence of forums/communities for exchanging experience or solving problems. These are a great support in the implementation of initiatives, helpdesks, etc.
- Communities' feedback on the use and adequacy of the products provided by the institution.

- Good documentation of the needs of emergency agencies and communities to manage flood risk and their translation into performance requirements for the E2E FFEWS.
- Agreements to get access to reports/papers developed from institutional data.
- Plans to raise awareness in the community about the relevance of hydrological forecasts in reducing risks to flood losses and in development of society.
- Possibility to involve the community in the maintenance and preservation of measuring stations.
- Increase in investment projects for improvements in flood forecasting as a result of increasing awareness of climate change, along with the consequences of its impact, as an economic and political issue at the national and international level.
- International, regional, national and local conferences, workshops and seminars for knowledge sharing.
- External training opportunities for staff and education exchange programmes.
- Students at university, master or doctorate levels interested in carrying out research projects with the institution.

Threats

- Reduction of annual national budget due to priorities being shifted towards other sectors.
- Change in the national government, which could shift the institutional steering committee, resulting in delays or degradation of current practices.
- Lack of political will and understanding of needs for hydrologic services in the country.
- Inadequate position for the institution within the national institutional structure and/or poor visibility within the national government.
- Dispersion of responsibilities and institutional roles due to the country's focus on other sectors.
- Lack of national awareness of risk management plans and their socioeconomic impact on the country.
- Weak governance arrangements between agencies delivering parts of the E2E FFEWS, leading to inadequacies in the service and impairing its effective delivery to users.
- Lack of trust and respect between agencies, spirit of competition.
- Limited recognition of (or investment in) EWS practices in national risk management plans.
- Lack of national laws/regulations authorizing the institution to issue products related to flood forecasts or flash flood guidance, and to meet needs of water resources users.
- Lack of a national early warning protocol for hydrometeorological events where the roles of the involved parties are well defined.
- Loss of existing historical data and/or physical records stored in vulnerable places.
- Natural events that could damage or destroy the observation network and/or headquarters.
- Stations and equipment vulnerable to vandalism.

- Stations that are not installed following regulations and standards.
- Inadequacy of models or techniques used for flood forecast.
- Lack of products that respond to user needs.
- Forecast products from web-based providers that are more pedagogical and interactive (thus more appealing) than those delivered by national services.
- Loss of user trust and confidence in forecasting products (as a consequence of previous false alarms, erroneous forecasts, etc.).
- Implementation of observation networks and development and dissemination of forecast products by national institutions or private companies, undermining the authority of the NHS and resulting in a loss of consistency in policies, products and messaging.
- Unbalanced gender policy/nonexistence of gender equality policies that could affect the participation of skilled people in key issues.
- Limited understanding of flood forecasting and warning requirements for vulnerable communities by national, regional or municipal authorities.
- Technology for hydrological and rainfall stations or equipment not adequate for country conditions.
- "Brain drain" (for example, because of an unstable economic situation in the country or high levels of insecurity).
- Lack of a national, regional or local strategy to increase community resilience in the face of climate change.
- Unplanned territorial growth and deficient waste management introducing changes to the natural dynamics and discharges of reservoirs and rivers that could lead to forecast failures.
- High cost of hydrological measurements and/or need to place them in areas that are difficult to access.
- Lack of equipment standardization and agency collaboration in the development, operation and management of hydrometeorological networks.

LIST OF ACRONYMS

AM	Assessment Matrix
CAP	Common Alerting Protocol
E2E FFEWS	End-to-End Flood Forecasting and Early Warning System
EWS	early warning system
FFEWS	Flood Forecasting and Early Warning Systems
FFI	Flood Forecasting Initiative
NDMA	national disaster management agency
NHS	National Hydrological Service
NMHS	National Meteorological and Hydrological Service
NMS	National Meteorological Service
NWP	numerical weather prediction
SWOT	strength, weakness, opportunity and threat
UNDRR	United Nations Office for Disaster Risk Reduction

GLOSSARY OF TERMS

This section defines certain terms that have been repeatedly used in the text and which the authors consider to be a potential source of ambiguity among readers. For definitions of technical terms, readers are referred to the following publications: *Technical Regulations* (WMO-No. 49), Volume III: Hydrology, *International Glossary of Hydrology* (WMO-No. 385), *Guide to Hydrological Practices* (WMO-No. 168), *Manual on Flood Forecasting and Warning* (WMO-No. 1072).

Public: In the context of the present guidelines, any individual living in the country served by the NHS is part of the public. The flood forecasts should be evaluated in the context of the public served by the NHS.

Stakeholder: Stakeholders are typically represented by an organization that plays a part in the End-to-End Flood Forecasting and Early Warning System and expresses their requirements regarding the forecast products. Examples include community groups and organizations tasked with emergency response, civil protection, water management, agricultural irrigation, etc. In many instances, stakeholders also provide useful information to the NHS such as field observations and information about reservoir releases, on-the-ground impacts, etc.

User: Users are members of the public or stakeholders who receive and use the products and services and who may provide feedback on the quality of the products and services.

Partner: A partner is an institution or organization that works in collaboration with the NHS to support and/or improve policies, procedures, models, forecast products and/or staff capabilities. Examples of partners could be a university that provides custom training to NHS staff on meteorology and hydrology topics, or an agency or engineering consultancy that develops improved hydrological models and shares them with the NHS.

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