ASSESSMENT OF

THE STATE OF HYDROLOGICAL SERVICES IN DEVELOPING COUNTRIES

GFDRR
Global Facility for Disaster Reduction and Recovery

WORLD BANK GROUP

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ABBREVIATIONS

AFD	Agence Française de Développement
APFM	Associated Programme on Flood Management
ARA	Administração Regional de Águas (of Mozambique)
DHM	Department of Hydrology and Meteorology (of Nepal)
DNA	National Directorate of Water (of Mozambique)
DRM	Disaster Risk Management
ECMWF	European Centre for Medium-range Weather Forecasts
GDP	Gross Domestic Product
GFCS	Global Framework for Climate Services
GFDRR	Global Facility for Disaster Reduction and Recovery
GIS	Geographic Information System
GloFAS	Global Flood Awareness System
GRDC	Global Runoff Data Centre
GWP	Global Water Partnership
HEPEX	Hydrological Ensemble Prediction Experiment
HLPW	High-Level Panel on Water
HSs	Hydrological Services
INFOHYDRO	Hydrological Information Referral Service (of the WMO)
IPCC	International Panel on Climate Change
IRD	Institut de Recherche pour le Développement
MCH	Meteorological, Climatological and Hydrological Database Management System
NFCS	National Framework for Climate Services
NHSs	National Hydrological Services
NHSUG	National Hydrological Services Users Group
NMHSs	National Meteorological and Hydrological Services
NMSs	National Meteorological Services
OECD	Organisation for Economic Co-operation and Development
SHS	State Hydrometeorological Service (of Moldova)
UIP	User Interface Platform (of the GFCS)
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNISDR	United Nations International Strategy for Disaster Reduction
USAID	United States Agency for International Development
USGS	United States Geological Survey
WBG	World Bank Group
WHYCOS	World Hydrological Cycle Observing System
WMO	World Meteorological Organization

EXECUTIVE SUMMARY

The pursuit of sustainable development and climate adaptation is increasing the demand for weather, climate, and water information and services to help protect lives and livelihoods from hydrometeorological hazards and optimize weather sensitive sectoral production. The core business of hydrological services is the provision of information about the water cycle and the status and trends of a country's water resources. Most typically, this focuses on assessing water resources, including drought monitoring and outlooks and flood forecasting and warnings.

Hydrological Services (HSs) are national public agencies mandated to provide basic hydrological information and warning services to the government, the public, and the private sector in support of protecting lives and livelihoods. HSs' aim is to fulfill the state and public need for robust water monitoring, data management, and prediction, providing authoritative and actionable information on hydrometeorological trends and extremes. HSs also deliver socioeconomic benefits through improved water resources and disaster risk management, with benefit–cost ratios frequently on the order of 3–4 and higher.

Yet, the World Bank Group (WBG) and the World Meteorological Organization (WMO) have become increasingly concerned that, particularly in low- and middle-income countries, HSs are unable to respond to the growing demand for easily accessible, robust, and timely information. As such, the WBG Water Partnership Program, the WMO, and the Global Facility for Disaster Reduction and Recovery assessed Hydrological Services in low- and middle-income countries to better understand their status, performance obstacles, and investment needs.

The assessment found institutional constraints consistently present in low- and middle-income countries, resulting in insufficient and ineffective Hydrological Services. The main obstacles identified include:

- Fragmented and myopic policy environments;
- Insufficient budgets;
- Inability to attract, train, and retain qualified staff;
- Limited and often declining hydrometeorological monitoring networks;
- Insufficient maintenance of hydrological infrastructure;
- Inadequate data management systems;
- Insufficient integration between hydrological and meteorological services;
- Poor connection with users;
- Inability to develop and provide hydrological products; and
- Unsatisfactory service delivery.

Recommendations for addressing these obstacles center around integrating hydrological services into national policies; focusing on core public missions; securing central government prioritization and support; exploring innovative financing mechanisms; strengthening partnerships with relevant public agencies, academia, and the private sector; leveraging new technologies and international data resources; strengthening interaction with users; and transforming institutions to focus on service delivery.

Considering the complexities of modernizing Hydrological Services, the development of a structured, costed, and long-term plan to support improved performance, based on sound economic and financial analysis, is recommended. Further, international good practice comprises the development of targeted user interaction mechanisms such as a National Hydrological Services Users Group (NHSUG). A NHSUG facilitates continuous coordination between providers and users of hydrological services, development and implementation of Hydrological Service modernization centered on user needs, and improved sustainability of services.

Meteorological monitoring facilities at the Xai-Xai weather station, Mozambique. *Source:* D. Kull, 2011.

CHAPTER 1
INTRODUCTION

The pursuit of sustainable development and climate adaptation is increasing the demand for weather, climate, and hydrological information and services to help protect lives and livelihoods from hydrometeorological hazards and to optimize weather sensitive sectoral production. Robust monitoring, data management, and prediction are needed to provide actionable information on hydrometeorological trends and extremes, such as floods and droughts.

National Meteorological and Hydrological Services (NMHSs) are public agencies mandated to provide basic meteorological and hydrological information and warning services. The importance of Hydrological Services (HSs)[1] as the source of national hydrological information, early warning, and related data services cannot be understated, with the global community highlighting the need to invest in early warning and anticipatory forecast-based actions at the 2017 Global Platform for Disaster Risk Reduction (UNISDR 2017).

The World Bank Group (WBG) initiative, *A Water-Secure World for All*, establishes the institution's vision for water: effectively managed as a critical resource for development to support agriculture, manufacturing, job creation, households, and the environment, with the entire population able to share this limited resource. In a water-secure world, countries can reduce and adapt to the impacts of a changing climate on water while ensuring its efficient use. This is not possible without accurate and understandable hydrological information that is supported by effective systems to communicate and deliver the information.

Yet, the WBG and the World Meteorological Organization (WMO) have become increasingly concerned that, particularly in low- and middle-income countries, HSs are unable to respond to the growing demand for easily accessible, robust, and timely information. It has been observed that:

- The roles, responsibilities, and contributions of HSs to sustainable development are not widely recognized by governments or the development community.

[1] The proper noun "Hydrological Service (HSs)" refers to specific institutions whose functions include hydrology; in many countries no single agency can be regarded as the National Service (WMO 2006). The common noun "hydrological services (hs)" refers to services provided by any institution.

- Investment in the provision of HSs is inadequate and often decreasing.
- Current international investments and technical assistance programs to strengthen HSs are neither effective nor sustainable.
- Protecting development gains and increasing prosperity calls for a new approach to assist countries to better manage their water resources—an approach based on improved Hydrological Services.

Gauging house in the Limpopo River Basin, Mozambique. *Source:* D. Kull, 2011.

CHAPTER 2
OBJECTIVES OF THE ASSESSMENT

The WBG Water Partnership Program, the WMO and the Global Facility for Disaster Reduction and Recovery (GFDRR) assessed HSs in low- and middle-income countries to better understand obstacles to performance and related investment needs. The assessment was conducted in three phases:

Phase 1: Rapid screening of global databases and reports, focusing on current HS capacity to respond to demand.

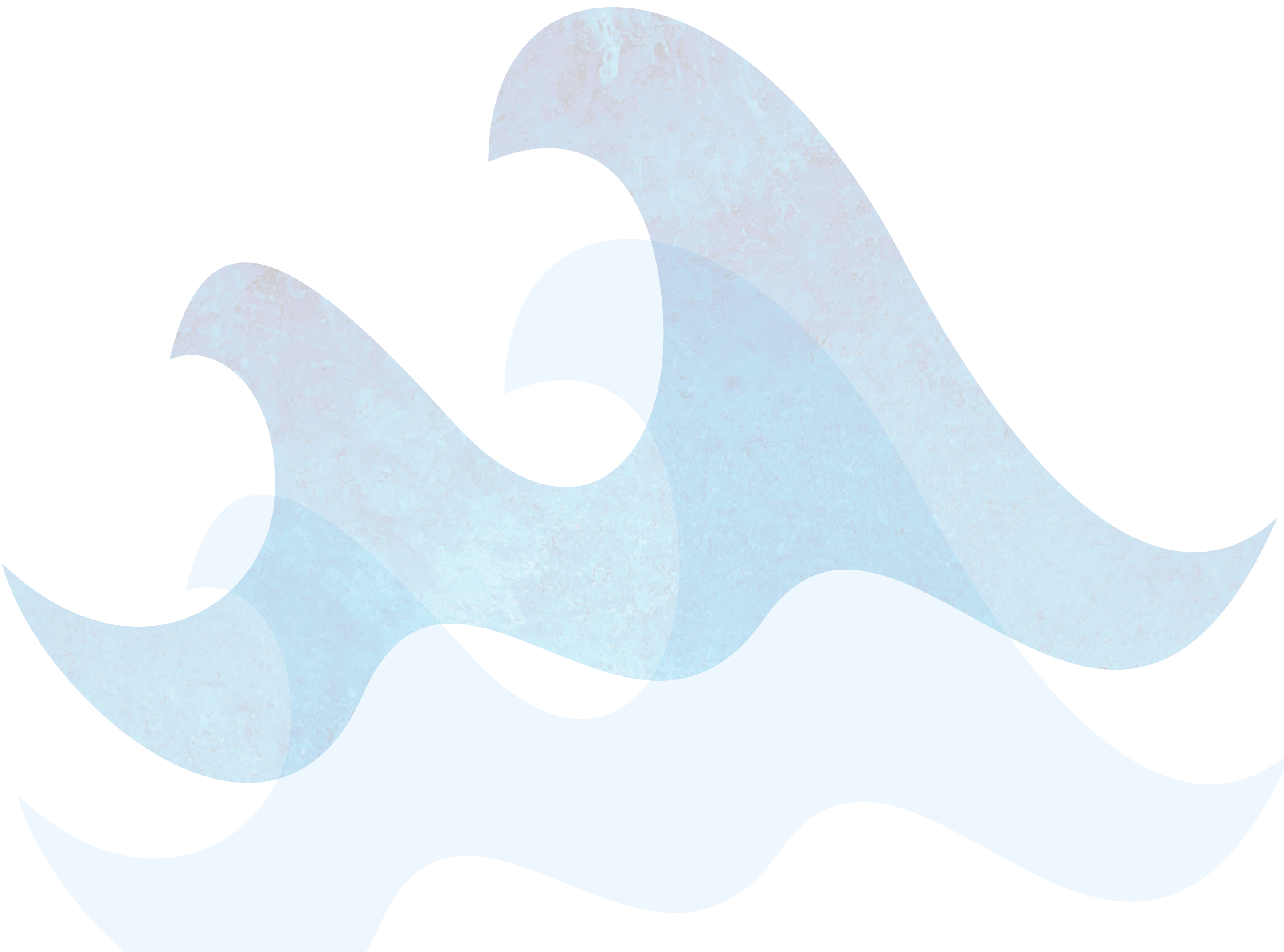
Phase 2: In-depth analyses of HSs in Cameroon, Madagascar, Senegal, and Tanzania.

Phase 3: Consolidation of Phase 1 and 2 sources, conclusions, and recommendations; over 75 (available) regional and national studies and reports (see Bibliography); and extensive expert interviews.

The global databases and surveys reviewed in the first phase include: WMO Hydrological Information Referral Service (INFOHYDRO), WMO Capacity Assessment of NMHSs in Support of Disaster Risk Reduction, WMO Survey on Assessment of the Current Levels of Service Delivery of NMHSs, and UN Water Country Briefs. These sources are all in some way limited, often outdated, or not globally representative due to limited sample size or self-reporting biases. But they provide valuable insights, particularly when consolidated and corroborated with regional and national studies and reports and with expert interviews with staff at the WBG; WMO; United Nations Educational, Scientific and Cultural Organization (UNESCO); Global Runoff Data Centre (GRDC); Agence Française de Développement (AFD); Institut de Recherche pour le Développement (IRD); and many national HSs.

This assessment aims to summarize the collected evidence, analytics, and recommendations and to provide an overview of the status of hydrological information and service delivery systems, particularly in low- and middle-income countries. While illustrating why HSs in most countries cannot meet the needs of their populations, the assessment emphasizes the benefits of modernizing and maintaining robust HSs while charting a path for sustainable investment. Modernization of HSs should enable nations to reach minimum standards to effectively manage water resources and disaster risks.

This assessment intends to provide a basis from which the WBG and other development partners can assist countries to strengthen the capacity, sustainability, and service delivery of HSs. Where possible, quantitative measures of services and infrastructure highlight the status in low- and middle-income countries. More qualitative and indirect metrics, such as user satisfaction and level of confidence in provided services, also inform the assessment.



CHAPTER 3
WHAT ARE HYDROLOGICAL SERVICES?

Hydrology is the scientific study of the movement, distribution, and quality of water on earth, including the hydrological cycle, water resources, and environmental watershed sustainability. Under ideal circumstances, a Hydrological Service is an institution whose core business is the provision of information about the water (or hydrological) cycle and the status and trends of a country's water resources. Most typically, this focuses on assessing water resources, including drought monitoring and outlooks and flood forecasting and warnings.

In most countries, Hydrological Service functions are dispersed among related water agencies (WMO 2006). Typically, the agencies have distinct functions but can have overlapping capabilities (such as modeling, research, and development of hydrological methodologies). The activities include systematic water resources data recording, collection, processing, storing, archiving, and rescuing; producing and disseminating data and information related to water resources; and hydrological forecasting with the dissemination of flood alerts and warnings (WMO 2011b; Adams and Pagano 2016).

The primary role of HSs is to provide information to decision makers on the status of and trends in water resources. Such information may be required, inter alia, for the following purposes:

- Assessing the status of a country's water resources (i.e., quantity, quality, and distribution in time and space), the potential for water-related development and the resource's ability to meet actual or foreseeable demand;
- Planning, designing, and operating water projects;
- Assessing the environmental, economic, and social impacts of existing and proposed water resources management practices, and planning sound management strategies;
- Providing security for people and property against water-related hazards, particularly floods and droughts;
- Allocating water among competing users, both within the country and across borders; and
- Meeting regulatory requirements (WMO and UNESCO 1991).

In most cases, water resources information is collected as part of an ongoing monitoring program or for a specific purpose, such as the design and operation of a hydroelectric power generation scheme. But

Guard at a station near Goba on the Umbeluzi River, Mozambique. *Source:* L. Croneborg-Jones, 2012.

the increasing scarcity of water resources requires a better understanding of competing needs and end uses, placing a much greater burden on the suppliers of water resources information. Further, the information must be interpreted for and provided in understandable terms and formats to a broad user community. Being fit for purpose, thus depends on understanding the needs of all (and not just the traditional) users of water resources information.

Even more demanding is projecting the possible data and service needs of future users and preemptively collecting the required information (WMO 2008b). One very good example of this is the increasing benefits of using seasonal climate outlooks presented in hydrological terms. For example, in Europe, the energy, water, and transport sectors have taken the lead in leveraging this information (Soares and Desai 2015). In California, the use of seasonal forecasts for high elevation hydropower production delivered a 1.2 percent increase in annual revenue (Rheinheimer et al. 2016). As competition for increasingly scarce water resources intensifies, such efficiency gains and a shift from passive collection to active integrated management will become business as usual.

CHAPTER 4
THE VALUE OF HYDROLOGICAL SERVICES

The High-Level Panel on Water (HLPW), organized by the United Nations and the World Bank Group, articulated a foundation for action, highlighting that to "take effective action we need to understand the importance of the water we have, and therefore must invest in data" (UN and WBG 2018). The HLPW specifically recommends for commitment ". . . to making evidence-based decisions about water, and cooperate to strengthen water data, such as through the HLPW World Water Data Initiative." This is to be achieved through a "An ambitious global framework . . . needed to enable public and private sector actors to cost-effectively access, use, and share water and hydromet data. Global and regional solutions can complement country systems since there are interlinked hydrological and climate systems."

Source: iStock.

The HLPW's World Water Data Initiative Roadmap of February 2017 outlines an agenda for improving access to water data, particularly by reducing costs and complexity for data users (UN and WBG 2018). Guidance material has been developed for countries seeking to improve water data policies, and strengthened water data responsibilities among multilateral agencies have been suggested.

4.1 • WATER RESOURCES MANAGEMENT

Water resources cannot be managed without the quantification of current and potential future distribution, quality, and variability. Public and private use of hydrological network data includes inter alia, planning, designing, operating, and maintaining multipurpose water management systems; preparing and distributing flood forecasts and warnings; designing spillways, highways, bridges, and culverts; mapping flood plains; determining and monitoring environmental or ecological flows; managing water rights and transboundary water issues; educating and researching; and protecting water quality and regulating pollutant discharges (USGS 2006). Sectors that rely on hydrological information include (listed alphabetically):

Agriculture, irrigation, and food security

Climate change adaptation

Construction

Disaster risk management

Education (schools)

Emergency response/civil protection

Energy

Environment management and ecosystem services

Fisheries

Forestry Industry

Insurance

Health

Land use and planning

Media

Municipal water supply

Recreation, aesthetics, and tradition

Regional and international cooperation

Research and development

Transport, navigation

Tourism

Water quality management

Water resources management

Watersheds management

The requirements for hydrological information and services vary within, between, and among countries, depending on the needs of users and the availability of water. For example, in Mali, almost all major urban centers are sited along the Niger and Senegal Rivers (along with the central inland delta) where water resources are concentrated. As long as there is capital for water treatment and distribution infrastructure, the riverine centers will have adequate access to river water and associated groundwater resources. More distant areas will face water stress, with the stress increasing northward as rainfall progressively declines. Lower rainfall, higher temperatures, and increased climate and weather variability are projected to affect agricultural production and the reliability of surface and groundwater resources.

4.2 • DISASTER RISK MANAGEMENT

Losses caused by hydrometeorological disasters continue to rise, with low- and middle-income countries experiencing the greatest impacts (IPCC 2012). Beyond the clear need to protect lives and property through disaster risk management (DRM), there is a growing understanding of the connection between natural hazards and poverty.

Since 2001, the World Meteorological Organization (WMO) and the Global Water Partnership (GWP) have promoted an integrated approach to flood management through the Associated Programme on Flood Management (APFM). The APFM's mission is "to support countries in the implementation of Integrated Flood Management within the overall framework of Integrated Water Resources Management to maximize net benefits from the use of their floodplains and minimize loss of life and impacts." They subsequently launched the Integrated Drought Management Programme. For both programs, hydrological services are of fundamental importance.

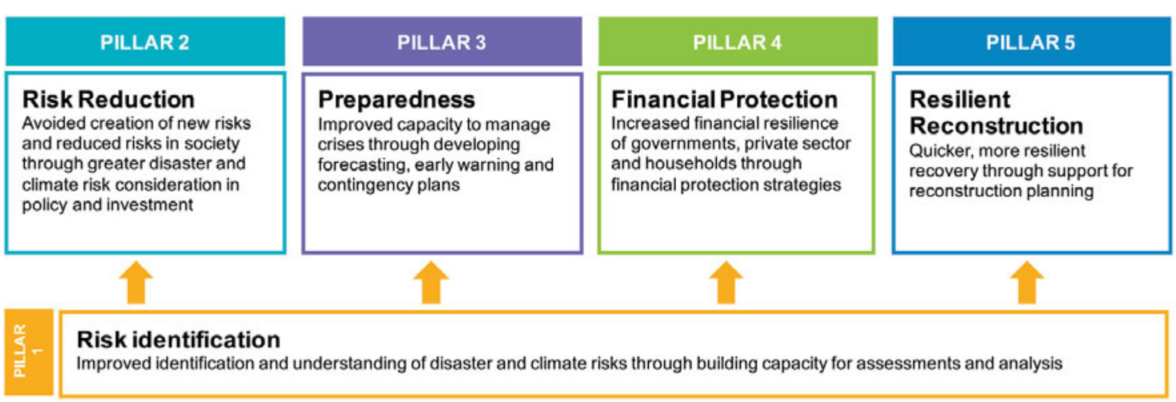
In 2011, the WMO articulated a global societal need for hydrological services through its Strategic Plan 2012–2015: "Poverty alleviation, sustained livelihoods, and economic growth (in connection with the Millennium Development Goals), including improved health and social well-being of citizens (related to weather, climate, water, and environmental events and influence)."

In 2013, the WBG established an operational DRM framework (Figure 1). The framework identifies the critical roles of HSs under Pillar 1 Risk Identification and Pillar 3 Preparedness.

In 2015, countries broadly recognized the importance of hydrometeorological services in support of DRM and endorsed the Sendai Framework for Disaster Risk Reduction (UNISDR 2015). Countries have committed at the national level "to promote the collection, analysis, management, and use of relevant data and practical information and ensure its dissemination, taking into account the needs of different categories of users, as appropriate . . ." and "to invest in, develop, maintain, and strengthen people-centered multi-hazard, multi-sectoral forecasting and early warning systems . . ." The 2015 UNFCC Paris Agreement also acknowledged the need to cooperate and enhance the understanding, action, and support in different areas, such as prevention and preparedness (including early warning systems).

In 2017, the WBG report "Unbreakable–Building the Resilience of the Poor in the Face of Natural

FIGURE 1 • **WBG Operational Framework for Disaster Risk Management**



Source: WBG (2013a).

BOX 1 • EFFICIENTLY REDUCING FLOOD LOSSES THROUGH EARLY WARNING

Rogers and Tsirkunov (2010) report that damage reduction due to forecast improvements can range from a few percentage points to as much as 35 percent of average annual flood damages. They propose developing standard flood damage categories that can be applied to specific water basins (as relevant) to assist in determining the socioeconomic benefits of forecast improvements.

Hawley et al. (2012) evaluated various flood risk management approaches. They find that forecasting and early warning systems have benefit–cost ratios second only to floodplain restoration and far greater than infrastructure projects, such as the construction of embankments, dams, dikes, levees, flood proofing, and flood diversions.

Pappenberger et al. (2015) estimated the monetary benefits of flood early warning in Europe based on the forecasts of the continental-scale European Flood Awareness System (EFAS), using existing flood damage cost information and calculations of potential avoided flood damages. The results provide clear evidence that there is likely a substantial monetary benefit, on the order of €400 for every €1 invested. This supports the wider drive to improve resilience to natural hazards by implementing flood early warning systems at the continental or global scale based on probabilistic flood forecasts.

Disasters" presented four major findings. First, efforts to reduce poverty and disaster risk are complementary. Second, natural disasters negatively affect well-being far beyond traditional estimates. Third, universal access to early warning systems significantly reduce well-being losses from natural disasters and increase the physical security of threatened societies. And fourth, investments in structural and nonstructural measures to reduce risk exposure that are supported as part of HSs activities, such as flood risk mapping and associated flood plain policy development, contribute to physical security.

The hydrological community recognizes that fully integrating DRM into planning and decision making is necessary to meet societal needs (Buchecker et al. 2013; Sivapalan et al. 2012). The International Association of Hydrological Sciences Panta Rhei Scientific Decade 2013–2022 supports the role of DRM within its proceedings (Montanari et al. 2013). Lopez et al. (2017) also state: "Researchers and practitioners are realizing the importance of integrating social, environmental, and economic aspects of flood risk management to improve flood risk reduction and mitigation actions." The benefits and cost efficiencies of early warning for floods are also well recognized (Box 1).

4.3 • QUANTIFIED SOCIOECONOMIC BENEFITS

Recognition of the importance of HSs has been difficult to establish and maintain among governments and key stakeholders. Past practices promoted hydrological monitoring networks based purely on the density of stations and the costs of establishing and maintaining the stations required to collect quality data. Sometimes, networks were justified by emphasizing and quantifying the socioeconomic benefits.

Starting in the 1970s, studies began to show the value of collecting hydrological data for managing hydrological events and disaster risks (Acres Consulting Services Ltd, 1977). In water-stressed regions susceptible to drought and prolonged water shortages, the need for integrated DRM and water resources management systems became clear. It also became apparent that environmentally displaced peoples and

Source: iStock.

forced migration would require policy responses and institutional reforms. Boano et al. (2008) recommend “adopting proactive development policies to address the potential migratory impacts of climate change which stress coping capacities, adaptation, and sustainability and which strengthen the incorporation of resilience strategies in programs and projects.”

In 2015, the WMO, the WBG, GFDRR, and the U.S. Agency for International Development (USAID) produced a report to help NMHSs and HSs develop a basic understanding of economic valuation methods, and thus enable them to design and commission further studies. “Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services” presents benefit–cost ratios greater than 1 and frequently on the order of 3–4 and higher for hydrometeorological services. The report also supports using the results to improve service delivery through business optimization, investment prioritization, and better communication with decision makers, users, and the public. Such assessments are increasingly being pursued and used to justify and optimize investments in NMHSs (Box 2).

This assessment found benefit–cost ratios between 1.5 and 7 for flood forecasting and warning services while, on average, a benefit–cost ratio of 9 for streamflow data. The importance of robust HSs has and will continue to increase as scarce and vulnerable water resources are developed and hydrometeorological risk is more intensely managed—all under increasing uncertainty. To this end, stream gauges with long records are particularly valuable as baselines.

Table 1 shows the results of this assessment’s targeted socioeconomic benefits studies. Using a benchmarking approach, the use of hydrological information is assessed among water-sensitive sectors and for mitigating water-related disaster losses as the percentage contribution to gross

BOX 2 • SOCIOECONOMIC BENEFITS OF STRENGTHENED HYDROMETEOROLOGICAL SERVICES IN SOUTHEASTERN EUROPE

The socioeconomic benefits of improved hydrometeorological services in Albania, Bosnia and Herzegovina, Croatia, the Former Yugoslav Republic of Macedonia, Moldova, and Montenegro (and partially Serbia) were assessed by the World Bank et al (2008). The assessment showed that strengthening Southeastern Europe's National Meteorological and Hydrological Services (NMHSs) and improving their products, information dissemination, and regional collaboration would yield significant benefits to national and regional economies.

In relative terms, Moldova, due to its very low gross domestic product (GDP), derived the biggest benefit (about 0.2 percent of GDP) while Croatia benefited about 0.05 percent of GDP. Motivated in part by this assessment, the governments of Albania and Moldova, with World Bank Group funding, have made major investments to strengthen their NMHSs. Southeastern European countries also are pursuing the South Eastern Europe Multi-Hazard Early Warning Advisory Services Project, which will deliver national and regional benefits (WMO 2017)

domestic product. Past studies, using different approaches, consistently show that benefits derived from HSs, and the data on which they are based, outweigh the costs incurred to establish and operate such systems. However, it must be stressed that the realization of potential benefits occurs only through actual delivery and use of quality services.

Yet, the identification of benefits from the use of hydrological data and information alone is not enough. Hydrological networks need to be cost-effective and efficient, and the data collected need to be fit-for-purpose. In addition, changes in user numbers, data use, and the information's intrinsic value (USGS 2006) need to be considered. The report "Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services" (WMO et al 2015) brings to light how expanded accessibility and (informed) use increases the value of and benefits from hydrometeorological services.

Further, ensemble hydrological forecasts and specific value-added services (which would include communicating forecast quality and uncertainty to users) can increase the cost–benefit ratio. For example, probabilistic flood forecasts and early warnings are critical to flood risk management. Additionally, rainfall intensity-frequency-duration curves and flood-frequency curves are used in the design of hydrological structures, including street drainage systems, flood retention structures, culverts, bridges, irrigation cannels, weirs, and major dams (spillways), and they constitute a significant class of hydrological services. But significant costs are associated with both under-design of these structures (e.g., the failure of major highways) and over-design (e.g., costs of construction), highlighting the potential cascading impact of the quality of hydrological services on the economic benefits that they either do or do not deliver.

TABLE 1 • Benefit–Cost Ratios from Modernizing Hydrological Services

Country	Benefit–Cost Ratio
Cameroon	12–43
Madagascar	2.5–11
Senegal	6–11
Tanzania	7.5–28

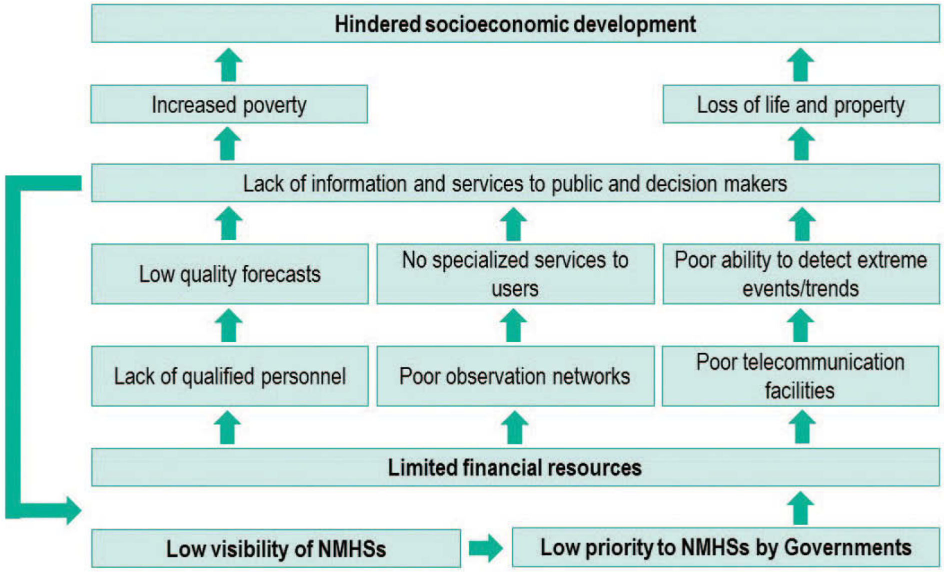
Source: iStock.

CHAPTER 5
STATUS OF HYDROLOGICAL SERVICES

Across low- and middle-income countries, the low visibility of Hydrological Services (HSs) sets off a virtual and self-sustaining cycle of little understanding (and thus low demand) among the public of HSs as a common good and among officials of HSs as a revenue generator from cost savings and improved efficiency of the economy. In a 2006 WMO survey/capacity assessment of National Meteorological and Hydrological Services (NMHSs) in support of disaster risk reduction, 75 percent of the participating countries declared a lack of visibility and recognition (WMO 2008a). Even in high-income Europe, 83 percent of the responses indicated this problem. Low visibility and recognition are a driving factor of HSs' low budget allocations (WMO 2007b).

Sometimes referred to as a "poverty trap," the existing poor status of HSs prevents the production of valuable data and information, so governments see no reason to invest in HSs (Rogers and Tsirkunov 2013). The schematic of the poverty trap shown in Figure 2 reveals how capacity limitations compound to reduce the positive impact of HSs, thereby contributing to their relative obscurity and

FIGURE 2 • **Hydrological Services "Poverty Trap"**



Source: Adapted from WBG et al. (2008).

non-importance in the eyes of governments, politicians, and the public.

Specific institutional constraints consistently emerge across low- and middle-income countries and result in ineffective HS performance and service delivery. The constraints in some way all relate to the "poverty trap," either by contributing to it or being caused by it. The constraints are reviewed in detail below.

5.1 • FRAGMENTED AND MYOPIC POLICY ENVIRONMENTS

Perceptions of the most pressing global risks based on their highest potential impacts, as identified by the World Economic Forum (2016), include the failure of climate change mitigation and adaptation, water crises, and large-scale involuntary migration. These risks also are viewed as having the greatest likelihood of occurrence. Omelicheva (2011) reports the effect of natural disasters on political instability is greatest for the most economically vulnerable and conflict-prone countries. Here, longer term water resources planning and management are critical.

As highlighted by the UN-WBG High Level Panel on Water, insufficient political awareness and leadership on water hampers global sustainable development; despite being a critical component in the global development agenda, water is often marginalized and left out of budgeting, legislation,

Bridge to enable profiling at the Baityk Station on the Alaarcha River, Kyrgyz Republic. *Source:* D. Kull, 2017.

BOX 3 • COHERENT SECTORAL POLICIES LEAD TO EFFICIENCY GAINS IN WATER RESOURCES MANAGEMENT

Effective governance for water resources management, moving increasingly from siloed to interdependent sectors, is becoming more complex, challenging, and costly. Coherence among policies that affect water resources is a critical principle for financing water resources management (OECD 2012).

Separate sectoral policies can make the cost of water management prohibitive, such that factoring water in and reforming the allocation of public moneys in these policies can be more cost effective than mobilizing additional funding in the water sector. The same is true for water resources monitoring. Countries often support parallel and duplicative hydrological networks, thereby increasing national costs and not fully leveraging available information.

and human resources mobilization decisions and discussions (UN and WBG 2016). In the context of water decisions themselves, HSs are often marginalized; water managers underestimate the investments needed for efficient HSs performance and service delivery (Box 3).

Strategic policies that ensure effective water and disaster risk management are needed. National development plans should include efficient water resources and disaster risk management (DRM), integrated when appropriate and possible, to pursue holistic and cost-efficient investment. Integration is especially critical in water-stressed regions that are susceptible to drought and prolonged water shortages. Such integration is often lacking at the national policy level. At the global level, sustainable water management is recognized as necessary for successful disaster preparedness, disaster risk reduction, and climate change adaptation (UN and WBG 2017).

Long-range water resources planning that is fully integrated with DRM and NHSs is a necessary common good. DRM in isolation from broader water resources concerns cannot meet pressing issues (e.g., poverty and environmental degradation), undermining sustainable development.

This assessment indicates that many countries are not integrating long-range water resources planning and DRM. The risks of droughts, floods, and climate change, which pose threats to the security and well-being of citizens, require shorter lead-time DRM and longer range water resources planning and management. For HSs, the required services overlap in terms of data, modeling, and decision support systems. But national policy environments are not sufficiently integrated and forward looking to enable this kind of operational integration.

It would be a mistake to consider HSs responsible for all water-related data collection and information production. Activities focusing on specific problems might be externalized and better conducted by other institutions in the public and private sectors. In this case, there needs to be formal clarity on the roles and responsibilities of each institution. Critically, an agency must be formally mandated to lead the coordination of relevant activities and set agreed standards. This should be the Hydrological Services or the Meteorological Services, depending on the national context.

TABLE 2 • **Financial Information for a Selection of Countries**

Country	Income Group (WBG 2016)	GDP (US$ million)	NHS Budget (US$ million)	GDP (%)
Madagascar	Low	9,880	0.150	0.00152
Senegal	Low	15,658	0.325	0.00208
Tanzania	Low	44,900	0.700	0.00156
Cameroon	Lower-middle	29,198	0.115	0.00039
Lao People's Democratic Republic	Lower-middle	7,000	0.598	0.00854
Philippines	Lower-middle	291,956	17.0	0.00582
Sri Lanka	Lower-middle	82,316	0.511	0.00062
New Zealand	High	173,754	12.74	0.00733
Uruguay	High	53,443	3.5	0.00655
Average				0.0038

Sources: Authors, UNISDR et al. (2013) and World Bank (2016).

5.2 • INSUFFICIENT BUDGETS

To compare and assess the financial resources provided to HSs by central governments, budget commitments as a percentage of gross domestic product (GDP) are used. Trends indicate that a global minimum of 0.02–0.03 percent of GDP should be invested in NMHSs (Rogers and Tsirkunov 2013). While such figures are not easily obtained for HSs specifically—depending on the importance of water to the national economy, the size of a country, and the distribution of the water resources—the required funding for HSs would most likely be similar. Table 2 shows the ratio of annual NHS budgets to GDP for a selection of countries and indicates low funding, particularly for low-income countries.

Low- and middle-income NMHSs operate in difficult economic contexts (Box 4). Many are under pressure to augment their central government budget allocation through fee-based services based on at least a partial cost recovery business model. In some cases, the overseeing ministry or a higher authority invokes such an approach.

BOX 4 • ECONOMIC REALITIES IN THE ZAMBEZI RIVER BASIN

In most Zambezi River Basin countries, financial austerity measures have weakened National Meteorological and Hydrological Services (NMHSs). The austerity has caused NMHSs to lose staff to retirement and the private sector; prevented the uptake of improved technologies to gather and analyze data and to prepare forecasts and warnings; and impeded delivery of warning information to disaster-management organizations (USAID and WMO 2011).

Direct government appropriations accounted for over 80 percent of NMHSs funding, while only 15–20 percent could collect fees for services (WMO 2012). This appears to be similar among HSs. The operating and funding models of HSs must consider the costs related to delivery of public and government-mandated obligations. These obligations should be taxpayer-funded (whether directly or indirectly through fees collected from user government agencies and ministries).

5.3 • INABILITY TO ATTRACT, TRAIN, AND RETAIN QUALIFIED STAFF

Most countries report inadequate staff numbers and staff training/capacity building; this requires urgent attention, especially to establish and maintain an appropriate gender balance (see Bibliography). In almost all cases in the developing world, the necessary institutions for hydrological monitoring have been established, but the professional depth and breadth of training and staffing varies.

The staff salaries of HSs tend to be low and noncompetitive, such that skilled and qualified staff often leave for better paying opportunities. It is also essential that HSs ensure the continuity of skills and timely replacement of retiring highly specialized staff. Modernization efforts need to find ways to address these challenges (Box 5).

Further, an institution's status within the government can hamper the ability and flexibility to offer employment packages commensurate with the needs of modern HSs. This has to do with the level of autonomy of the HSs and ministry-imposed standards. The possible statuses of HSs range from a non-autonomous department unit, increasing in autonomy as a contract agency, public body, state-owned enterprise, and finally, a fully privatized company (Rogers and Tsirkunov 2013). For example, the Moldova State Hydrometeorological Service (SHS) has sought over the last few years to change its status from a departmental unit to a contract agency or even public body for many reasons, including the ability to offer more competitive employment packages. Unfortunately, this has not happened, and the SHS's ability to retain the skilled staff required to operate sophisticated observation

River monitoring equipment at the Baityk Station on the Alaarcha River, Kyrgyz Republic. *Source:* D. Kull, 2017.

BOX 5 • SUSTAINABLE STAFFING CHALLENGES IN NEPAL

Nepal's Department of Hydrology and Meteorology faces constraints in recruiting and retaining a qualified workforce, and thus risks losing the qualified staff needed to run a modernized hydrometeorological system. To mitigate this risk, the Department worked with the Ministry of Finance and the Ministry of General Administration on an "Operations and Management" study to inform future staffing needs. The Department is considering a performance-based scheme that remunerates staff based on their contributions to tangible outputs (WBG 2012).

and forecasting equipment remains constrained (WBG 2017b).

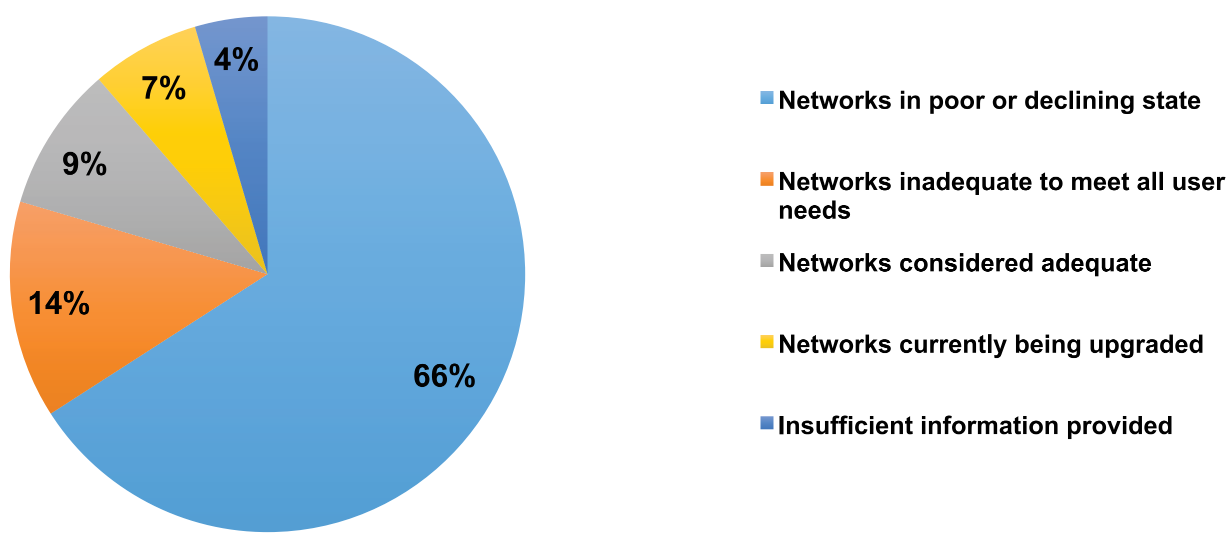
While many HSs are receiving funding to upgrade their technology, they struggle to ensure sufficient human capacity to fully utilize new systems. For example, the Hydrology Division of the Sri Lankan Department of Irrigation is in a state of transition, especially in its flood forecasting and warning functions. It is moving from a largely manual mode of operations, with limited modeling capabilities, to a more automated environment, with improved data-handling technology and with significantly improved modeling capabilities. However, the workforce remains strongly oriented toward technical expertise and continues to lack professionally qualified staff. In some countries, the HSs and the academic sector are not sufficiently engaged, or there might not even be local universities offering education in disciplines relevant to hydrological services. In both cases, the local talent pool remains constrained.

5.4 • LIMITED AND OFTEN DECLINING HYDROMETEOROLOGICAL MONITORING NETWORKS

Observation networks consist of observation stations as well as data transmission, telecommunication networks, data processing, and storage systems, that is, data management systems. Based on the information collected in this assessment, HSs report significant under-capacity in their monitoring networks (Figure 3).

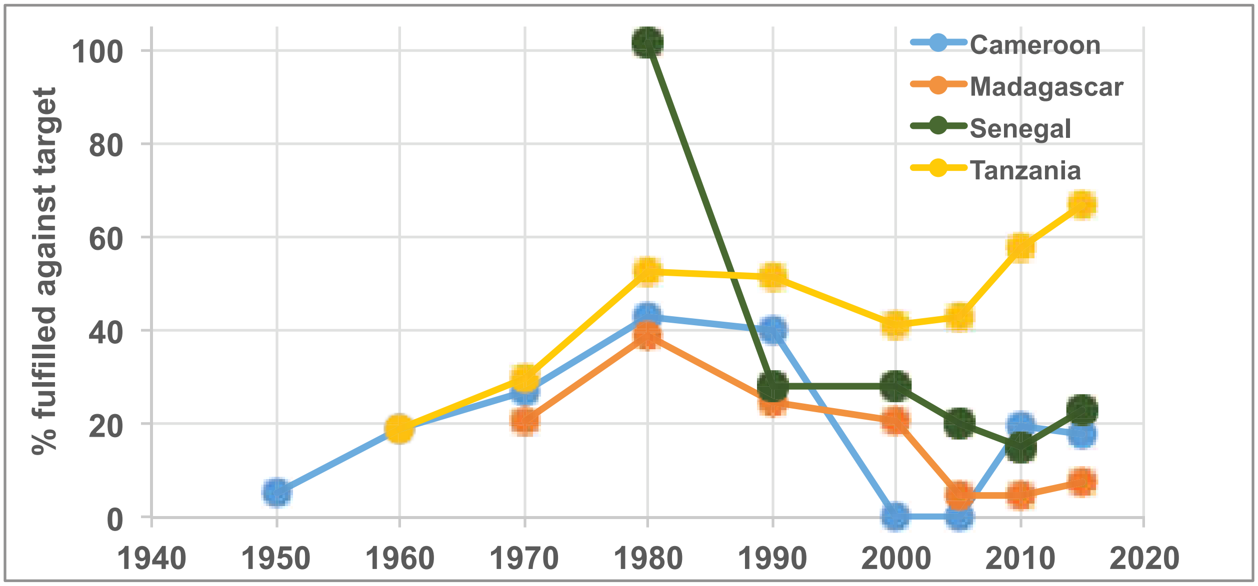
In the surveys reviewed for this assessment, 72 percent of water professionals stated their country needed more water monitoring stations, and 78 percent of low- and middle-income countries and 86 percent of least developed countries believed their networks did not meet the current needs.

FIGURE 3 • **Status of Hydrometeorological Observation Networks in Developing Countries**



Source: World Bank Group based on all listed references (2018).

FIGURE 4 • **Trends in Hydrological Observation Network Size in Four African Countries, as Compared to WMO Minimum Guidelines**



Source: World Bank and Water4Life (2016).

Figure 4 provides detailed data on the decline in hydrological networks in four African countries.[2] For example, of the minimum target number of stations in Madagascar in 2015, only 7 percent were operational.

The current number of reporting stations is well below the historical maximum and far below the minimum target number of stations (as guided by WMO 2008b). In many countries, the potential use of data for real-time water resources management is not realized due to a lack of telemetry (automated monitoring and communication) and data processing and management systems. In some countries, telemetry systems are in use at a limited number of stations. Other countries have no telemetered stations at all. In this context, WMO is revitalizing its World Hydrological Cycle Observing System (WHYCOS) program through a new initiative, the Global Hydrometry Support Facility (HydroHub) to enhance, consolidate, and sustain hydrologic monitoring systems around the world, catalyzing changes including facilitating the operational uptake of innovative hydrometric technologies and measuring approaches by NMHSs. Based on the 2015 WHYCOS Guidelines (WMO 2015b), a new WHYCOS framework is under preparation that will include, in addition to the innovative approaches, the establishment of simple hydrological products and services within HYCOS projects.

5.5 • INSUFFICIENT MAINTENANCE OF HYDROLOGICAL INFRASTRUCTURE

Of the studies reviewed for this assessment, all countries report having insufficient staff and financial resources to operate and maintain their national hydrometeorological observation networks. Automatic stations require continual investment, and they need to be refreshed every 10 to 15 years. Hazard events such as floods, lightning strikes, and vandalism can damage a

[2] It should be noted that the data are not consistently reported.

station beyond repair, but even limited damages to simple, inexpensive items such as staff gauges are often not repaired. In many cases, straightforward tasks such as routine maintenance are neglected while data records and validations are lost. This can be due to a lack of proper training and validation equipment (e.g., land survey instruments for providing datum adjustments of water-level monitoring devices, current meters, or velocity profilers to maintain stage-discharge relationships).

The ongoing maintenance of hydrological networks and the establishment and maintenance of a hydrological information system to enable access to data and information are also necessary operational parts of fully functional HSs. In a study of the Nigerian streamflow observation network (Royal HaskoningDHV 2015), the main challenges, as found during an inspection of the sites, were:

- Some channels appear unstable, causing nonrepresentative measurements of the water conditions;
- During flood flows, the rivers carry alluvial material; the material can distort the measurement of the water level and at worst, destroy the water level measurement equipment;
- The equipment ceased to be maintained; and
- Vandalism occurred at some sites.

In many countries, even where HSs stations are in operation, there are high percentages of missing water level/discharge data. For example, in Senegal, the percentage of missing data varies from 24 to 38 percent. This reflects the difficulties that HSs face in operating hydrometric networks. The main reasons for discontinuity of the data reported in HSs are lack of spare parts, lack of maintenance due mainly to limited financial resources, lack of calibration, and vandalism, in addition to the limited capacity of field hydrologists to cope with modern technology. Multiple challenges afflict the sustainability of observations networks in the Zambezi River Basin, a river network that is critical to the well-being and development of the countries and peoples in the basin (Box 6).

In many instances, development assistance has been provided to low- and middle-income countries to build new and improved networks. In fact, critical investment is needed to strengthen HSs capability to maintain infrastructure and deliver basic services. Systems often fall quickly into disrepair awaiting the next tranche of development assistance for their upkeep.

BOX 6 • CHALLENGES OF HYDROMETEOROLOGICAL NETWORKS IN THE ZAMBEZI RIVER BASIN

In the Zambezi River Basin, data collection networks are in a state of decline, with hydrological networks suffering greater losses than meteorological networks. Most stations operate manually and collect little real-time data. WMO Hydrological Cycle Observing System stations suffer because of insufficient numbers of qualified staff and financing for travel, repair, periodic maintenance, and sensor replacement. The basin's hydrometeorological networks generally have limited gauges, such as real-time meteorological observation stations, rain gauges, and streamflow gauges. Rating tables for river water level gauges are increasingly becoming outdated because discharge measurements are not being taken (Pilon and Asefa 2011).

5.6 • INADEQUATE DATA MANAGEMENT SYSTEMS

Adams and Pagano (2016) state: "It's surprising how universal some problems are, such as data. Water is both a necessity and a hazard; for forecasters, the same is true for data. Data are our lifeblood and yet they can also be our downfall, such as when they are poor quality." This applies to any hydrological information, service, or product: it will only be as good as the underlying data and information on which it is based. The recognized need for good systems to manage hydrological data is considered a priority even in resource-constrained environments (Box 7).

The Hydrological Services of many low- and middle-income countries do not have access to modern hydrological information systems. Their data are often held in paper archives or simple spreadsheets. Based on an analysis of the studies in the Bibliography, 64 percent of countries need to upgrade their data management systems, while 13 percent are in the process of having their data management systems upgraded (Figure 5). Based on reported dissatisfaction with current systems, it appears that modern water resources data management systems are not being used in many countries to maximize the value of their monitoring programs. Many of the current data management systems require extensive customization or replacement to link monitoring networks to national and regional information systems.

Quality assurance and quality control of data are other issues among countries. Modern data management systems embed a data quality management framework, but countries do not regularly control for data quality. In this context, the WMO is promoting an open-source data management system, the Meteorological, Climatological and Hydrological Database Management System (MCH), for application through a community of practice that includes technical assistance and training activities for low- and middle-income countries. As of 2018, 28 countries have installed the MCH System and at least 9 of them use it operationally.

There is also a distinct lack of evidence of data sharing and exchange among riparian countries. While this is often politically driven, the reported limitations of data collection and management do present a barrier to data sharing even if the

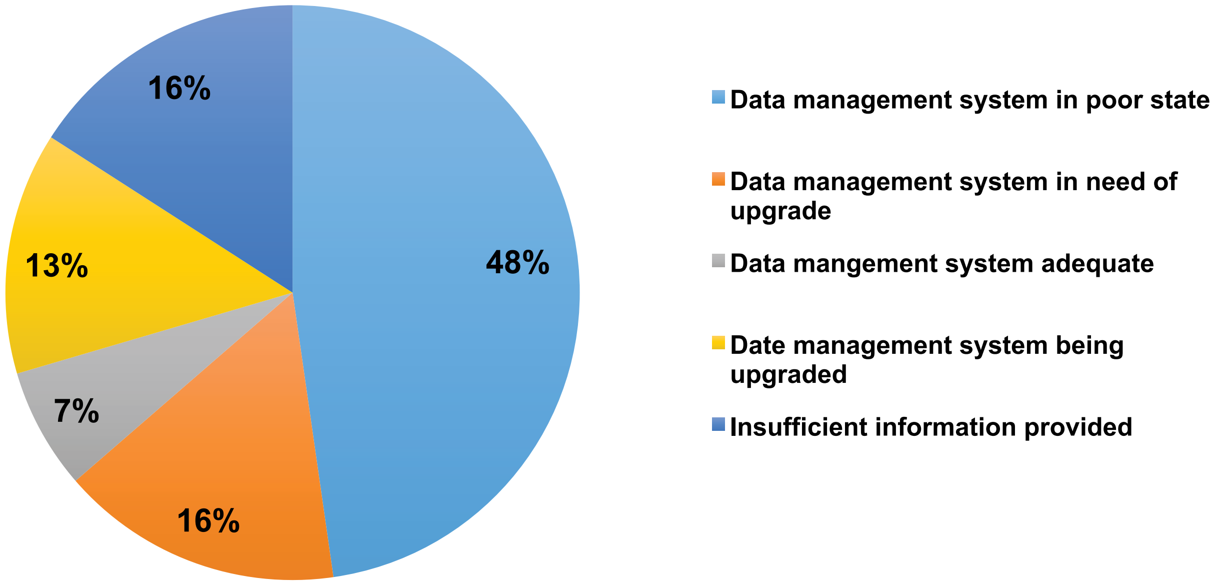
BOX 7 • CREATIVE DATA MANAGEMENT IN MOZAMBIQUE

In resource constrained environments, inventive low-cost approaches to data management and transmission are common and can include outdated software and operating platforms. Such was the case in Mozambique in 2013.

The Regional Water Authorities (ARAs) received handwritten hydrological observations and manually entered them into Excel or water-specific software, such as HYDATA (the MS-DOS version) and HYDSTRA (with significant licensing fees). This was transmitted to the National Directorate of Water (DNA) for consolidation and archiving. For simulations, the ARAs and DNA used a host of models, including MIKE11, HEC-RAS and WAFLEX, all of which had to ingest the different formats; often Geographic Information System (GIS) packages were run in parallel.

A subsequent WBG-financed project aimed to harmonize hydrological data management under a common and integrated/interoperable system across scales and institutions (WBG 2013b).

FIGURE 5 • **Status of Hydrological Data Management Systems in Developing Countries**



Source: World Bank Group based on all listed references (2018).

protocols for such exchange exist. In this context, it is encouraging to note that interagency data exchange is actively taking place in some countries despite limitations of the networks and data management systems.

5.7 • INSUFFICIENT INTEGRATION OF HYDROLOGICAL AND METEOROLOGICAL SERVICES

Hydrological Services are dependent on meteorological data in the form of quantified estimates of observed and forecasted precipitation and temperature, as well as such environmental variables as dew point, wind speed and direction, and solar radiation. Most of the monitoring data are gathered through automated weather stations, radar, and satellite remote sensing, while forecast data and products are obtained from numerical weather prediction model forecast systems as a matter of course by National Meteorological Services (NMSs). Too often these data and products are provided to HSs as inputs for hydrologic modeling as an afterthought, without consideration of required data formats, timeliness, and delivery methods. HSs are forced to improvise with data and weather forecast product delivery that is generally inadequate for their needs.

In resource challenged contexts, "information is power" can cause divisions between Hydrological Services and National Meteorological Services or even within a National Hydrometeorological Service, with formal government entities not sharing critical data. In one National Hydrometeorological Service, the hydrological forecasting unit purchased rainfall forecasts from an international third-party provider (which in the majority of the cases do not provide information on the quality of their data and products), while sitting in the same building and under the same management as the meteorological observation and forecasting unit. This was not only cost inefficient; it also meant the hydrological services were neither benefiting from local meteorological expertise nor the advances being made by WMO World Meteorological Centres (WMCs) and Regional Specialized Meteorological Centres (RSMCs), with the use of quality-assured global and regional forecast products from numerical weather prediction systems, including ensemble forecasts. This prevents the application of ensemble hydrological forecasts and the communication of forecast quality and uncertainty to users, which can lead to poor decision making.

Similarly, meteorological services largely control and dominate data and network infrastructure, particularly in the case of National Hydrometeorological Services. This presents inefficiencies in producing and delivering HSs forecasts to meet user needs.

5.8 • POOR CONNECTION WITH USERS

Lopez et al. (2017) discuss the need for strategies to increase social preparedness. They point out that communicating with Hydrological Services experts is a must. Too often the concerns and needs of users are either ignored or receive too little attention. WMO (2014) highlights:

> "The user of weather-, climate-, water-, and environment-related information is at the center of effective service delivery. . . . The role of the provider is to identify these users, including intermediaries, to understand their needs and determine how NMHSs can meet those needs, either individually or in partnership with other providers and partners. The evaluation of user needs is not a one-time requirement but a continuous and collaborative part of the service delivery process."

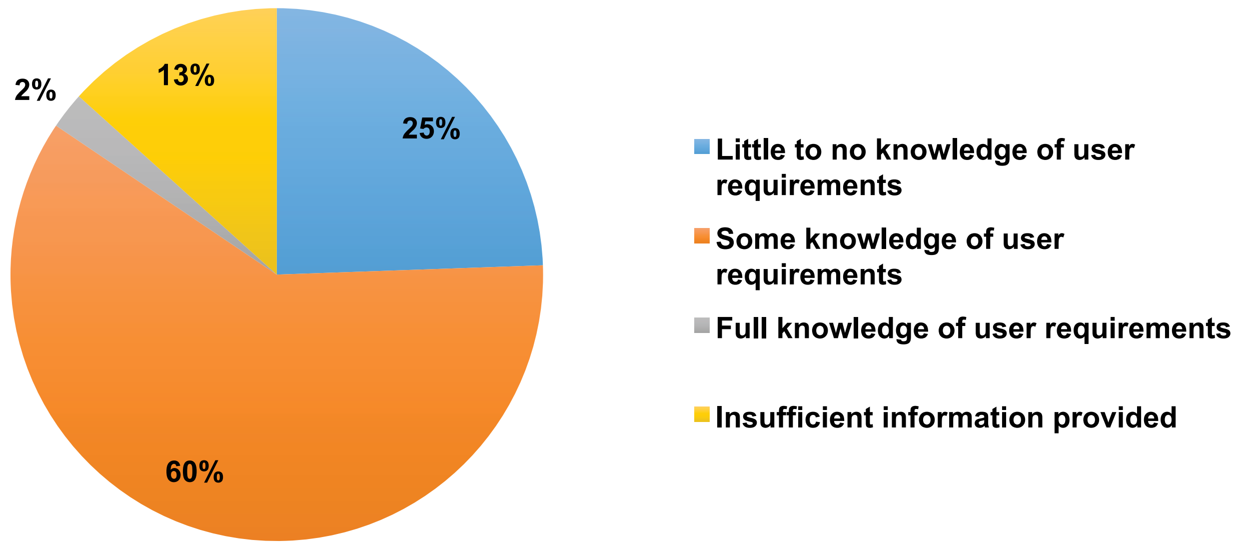
HSs do not proactively identify their end users, potential commercial customers, or the real needs for services (WBG 2008). Based on the material collected for this assessment (see Bibliography), 62 percent of countries had better than a limited understanding of the users of hydrological information and services, while 13 percent had no understanding (Figure 6). This utility and potential benefits of hydrological services cannot be leveraged without public awareness and common demand for such services.

Water resources management involves complex social issues that require an understanding and consideration of diverging values and perceptions (Jacobs and Buijs 2011). But there generally are challenges in identifying user needs (WBG 2008):

- Engrained focus on limited hydrometeorological services for a few traditional services, leading to a lack of tailored, timely products for different end users;
- Users' being unwilling (or unable) to pay for new services;
- Users being unaware of potential services that could be achieved and provided using modern technology; and
- Little real information in HSs about potential uses of hydrometerological information by different socioeconomic sectors.

To close the gap between providers and users of hydrological services, it is critical to deepen the understanding of who end users are, what they need, and how HSs can meet these needs. Procedures are required to determine the different users' water information needs. It is

FIGURE 6 • **Hydrological Services Knowledge of User Requirements**



Source: World Bank Group based on all listed references (2018).

essential that the design and updating of data collection networks be coordinated with the user community. This will ensure that stations for monitoring the various elements of the water cycle are sufficiently related, both in number and location, to achieve an integrated network that supports the users' demands for services. Such an approach would enhance the information content of the data sets for both current and unforeseen future needs.

With the growing recognition of global climate change and the environmental impacts of human activities (e.g., urbanization), there is an increasing emphasis on the information required for sustainable development and water resources management. The diversity of the possible uses of water resources information implies a considerable range of data and product types. However, particularly for newer products such as seasonal forecasting, the interaction between actors, usability of the information provided, and influence of institutional and social factors are important aspects influencing effective usage (Soares and Dessai 2015).

5.9 • UNSATISFACTORY SERVICE DELIVERY

The WMO (2014) highlights:

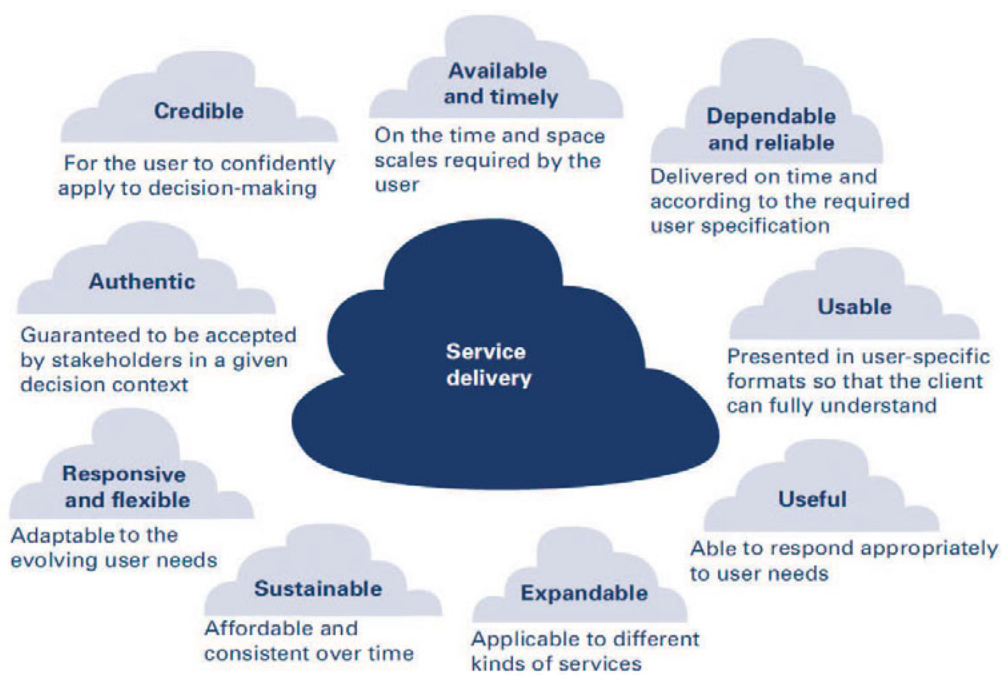
> "The core business of NMHSs is built around their responsibility to provide essential weather, climate, and related information to the community at large. In the provision of weather-, climate-, water-, and environment-related services, it is essential to put the users first. It is only by fully understanding why they need our services and how they use them in their decision making that we can provide services which are optimal. By striving to provide services that best meet these needs, NMHSs ensure that they fulfil their statutory obligations and are consequently held in high regard by the public, governments, and users."

Limited information is available on user satisfaction of HSs. However, user satisfaction surveys undertaken in some countries as part of the assessment show most satisfaction levels being below 50 percent. A recent WMO global survey (2015a) indicated through self-assessment that 5–10 percent of NMHSs consider themselves to have "undeveloped" service delivery, while 15–23 percent have initiated development but are not yet at higher levels of service delivery, namely "development in progress," "developed," or "advanced." While the survey focused broadly on NMHSs, the reported trends also apply to HSs. And there is a concentration of particularly low-income countries in these lower states of service delivery.

The WMO (2014) highlights the qualities of effective service delivery (Figure 7) and outlines six strategic elements in ensuring service delivery: (i) evaluate user needs and decisions, (ii) link service development and delivery to user needs, (iii) evaluate and monitor service performance and outcomes, (iv) sustain improved service delivery, (v) develop skills needed to sustain service delivery, and (vi) share best practices and knowledge.

Before the full value of the hydrological services can be recognized, there is a fundamental requirement. HSs must have the ability to move data up and products through the data value chain, from data and information collection to user-orientated services for decision making. It is essential that the data collection be fit-for-purpose and transformed into the services and products required by the user community, whether a flood forecast and warning or information for the design, construction, and operation of hydrological structures: ". . . services do not generate economic and social value unless users benefit from decisions as a result of the information provided, even if the services are of the highest quality" (WMO et al. 2015).

FIGURE 7 • **Qualities of Effective Service Delivery**



Source: WMO (2014).

CHAPTER 6
RECOMMENDATIONS

This assessment documents the challenges facing Hydrological Services (HSs) in low- and middle-income countries. While the below recommendations have to some degree been tested, they should be pursued through a context-specific approach that allows for refinement to best support HSs (Table 3).

TABLE 3 • **Recommendations to Help Address Identified Obstacles**

Obstacles	Recommendations
Fragmented and myopic policy environments	• Advocate and support integrated policies that highlight the national need for hydrological services at the ministerial level. • Develop robust and flexible national action plans for hydrological services, taking local factors into consideration. • Raise peer pressure through existing global commitments.
Insufficient budgets	• Assess, quantify, and advocate for the socioeconomic and development benefits provided by NHSs. • Advocate for HSs by users, particularly parliaments, government ministries, and agencies; this is more effective than self promotion. • Focus on the mission: ensure delivery of basic services (WMO 2006) before pursuing specialized service delivery. • Leverage international capital investment opportunities and the improved services they deliver to pursue an increased core budget. • Investigate potential for public–private partnerships to strengthen financing streams or offload noncore business costs.
Inability to attract, train and, retain qualified staff	• Improve the formal government status of HSs to enable offering of competitive employment packages. • Implement career management and training programs aimed at professional certification and growth. • Pursue external opportunities to finance appropriate national and international capacity-building opportunities. • Establish partnerships with the academic sector for training in water professions, including hydrological technicians.

(continued)

Obstacles	Recommendations
Limited and often declining hydrometeorological monitoring networks	• Develop and implement monitoring network design and optimization techniques that integrate different measuring sources and approaches. • Identify and invest in critical monitoring needs and locations. • Pursue external capital investment to rehabilitate and/or modernize monitoring networks.
Insufficient maintenance of hydrological infrastructure	• Ensure long-term institutional commitment of specifically allocated resources for maintenance. • Investigate potential (cost-effectiveness and efficiency) of outsourcing maintenance to commercial providers, while ensuring adherence to national and global standards and norms. • Investigate focusing some development assistance for low- and middle-income countries on strengthening the capability of HSs to maintain existing infrastructure and deliver basic services. • Advocate and support identification and adoption of innovative and robust technologies that can provide sustainable solutions to hydrological monitoring.
Inadequate data management systems	• Install modern, user-friendly, flexible interoperable and low-cost (open source) data management systems.
Insufficient integration between hydrological and meteorological services	• Develop national plans and operational procedures that bring hydrological and meteorological services together as a cooperative enterprise. • Quantify the benefits of open data approaches between hydrological and meteorological services.
Poor connection with users	• Establish a National Hydrological Services User Groups (NHSUG) involving all stakeholders. • Implement formal and regular feedback mechanisms (e.g., satisfaction surveys, face-to-face discussions), incorporating a follow-up mechanism as appropriate. • Improve product and service dissemination mechanisms and systems for reaching all user groups/sectors. • Investigate potential of public–private partnerships to strengthen user connectivity.
Inability to develop and provide hydrological products	• Address data collection issues through the above mechanisms to ensure data are available. • Develop the capacity of HSs to prepare and disseminate hydrological products and services, including hydrological ensemble forecasts, through existing or newly developed capacity building mechanisms.[3] • Ensure some development assistance is focused on developing and delivering products and services to meet user requirements.
Unsatisfactory service delivery	• Develop and implement a strategy for service delivery.

To escape from the so-called "poverty trap," HSs need to transition toward knowledge-based and service-oriented institutions, without losing capacity for rigorous scientific and technical activities. Such institutional modernization generally requires decades, spanning far beyond the normal life cycle of individual development projects. It also requires visionary, strong, and flexible leadership that understands good practice in change management.

[3] For example, participation in the Hydrological Ensemble Prediction Experiment (HEPEX: https://hepex.irstea.fr) and through exploiting large-scale flood forecasts through the Global Flood Awareness System (GloFAS: http://globalfloods.jrc.ec.europa.eu) operated by the European Centre for Medium-range Weather Forecasts (ECMWF) (Cloke, 2017).

If Hydrological Services do not transition to a service delivery business model, traditional development projects will continue to support HSs for a limited period without long-term sustainable results. Generally, it will take the form of investing heavily in new equipment with training plans too concentrated in time and with no real possibility for the trainees to take ownership of new knowledge and how to make best use of the knowledge. As indicated in many evaluations, most HSs development projects have suffered and not achieved sustainability because participating countries are not committed to allocate sufficient ongoing operations and maintenance funds. As highlighted, WMO is exploring solutions for this challenging issue through the HydroHub initiative and the new WHYCOS framework, but again, this is often driven by a lack of recognizable and effective user-oriented service delivery, reducing institutional support and resourcing for operations and maintenance.

As indicated above, current international investments and technical assistance programs to strengthen HSs have not been fully effective or sustainable. This is due in part to the disconnect between (i) the funding to improve data collection and management and to develop products and services and (ii) the delivery and ongoing funds required to continue these operations. It is essential to bridge this divide.

It is impossible to modernize HSs and to ensure their utility to society without strong government commitment to increased financial support, establishment of effective public–private partnerships, investment in capacity building and staff training, and strong and active national and regional cooperation. National cooperation must begin with interagency cooperation between the key players, including, but not restricted to, the National Meteorological Services, DRM agencies, and water resources management agencies at the national and local levels. In many instances, such interagency relationships are poor and, in some cases, prohibitive.

Assessing demands and priorities with current and potential users is not easy. In many countries, decision makers assume existing hydrological records suffice to resolve most of the present problems. They ignore that under a changing climate, it is no longer possible to assume the future hydrological record will follow the historical record. Developing, implementing, and nurturing national hydrological services action plans and user groups can help HSs deliver better and more user-targeted services. This, in turn, increases their visibility and recognition and leads to increased demand and support.

6.1 • NATIONAL HYDROLOGICAL SERVICES ACTION PLAN

Considering the complexities of modernizing hydrological services, the development of a structured and costed long-term plan to support HSs in improving performance, based on sound economic and financial analysis, is recommended. Such modernization plans can include, as appropriate to the given context, at least the following components:

- Strengthening of management, including human resources, financial management, project management, innovation, governance, and legal and regulatory support.
- Pursuing service delivery improvement in line with the WMO Service Delivery Progress Model (Annex 1 of WMO 2014).

- Improving sustainability and behavioral change through innovations such as change management, public–private partnerships and development of enhanced communication and outreach programs.
- Rehabilitating technical infrastructure, including observation networks, monitoring equipment, data management systems, assessment and forecasting tools, communication systems, and IT support systems.
- Developing technical capacity and educating through a training plan to build the required skills to cope with the innovation, modernization, and sustainability of the enhanced systems.
- Devising a timeline and cost estimates of the above improvements, considering sustainability issues and, particularly, operations and maintenance costs.

Staff gauge at the Chingodze Station on the Revuboe River, Mozambique. *Source:* D. Kull, 2012.

It is further recommended that the country lead the development of these plans and integrate them into the national action plans/strategies. To proceed, it is necessary to establish a business case around the collection, use, and delivery of hydrological information and services. In broad terms, the business case must address the following features:

- *Customer focused:* Users of hydrological information and services must be included in product planning and design from the outset; the derived information and services must respond to user needs. It is proposed to establish a National Hydrological Services User Groups (NHSUG, see section 6.2) to ensure interaction between government and nongovernment providers and users. Review and feedback mechanisms are needed to ensure improved and new capabilities are leveraged.
- *Services tailored to meet the needs of end users,* and delivered through the most appropriate mechanisms.
- *Fit-for-purpose networks, instrumentation, information management systems, and service delivery mechanisms:* Approaches to data collection and services delivery must be identified and established in the most cost-effective and efficient manner. Duplication is to be avoided.
- *Use of internationally available products:* Where possible and helping to achieve economic efficiency, optimum use should be made of internationally available services and products, such as satellite products, numerical weather prediction/ensemble prediction systems (NWP/EPS) data and products, and flood forecasts from the Global Flood Awareness System (GloFAS) operated by the ECMWF.
- *Funding mechanisms:* Some hydrological information and services are public goods by nature; governments have a key role in funding such activities. Private benefits also can be derived from high quality hydrological information and services; the potential for and benefits of public–private partnerships and funding models should be considered.

Development partners such as the WBG and the WMO should work closely with Hydrological Services to establish projects that support and are integrated in modernization plans, enabling:

- Initial investment in upgrading of the fit-for-purpose national hydrological network to meet an agreed set of country needs and driven by the user community (NHSUG);
- Establishment of a supporting holistic hydrological data and information system(s);[4]
- Establishment and delivery of a set of agreed national and user-targeted hydrological services;
- Establishment and implementation of a capacity-building strategy for the HSs staff to facilitate the sustainability of the above actions;
- Development of a funding model to enable the sustainable operation and maintenance of the systems and services, including the appropriate government funding; and
- Finalization and adoption of HS business plans.

[4] An organized set of resources (e.g., staff, data, procedures, hardware, and software) enabling the collection, storage, organization, development, and dissemination of data and information (including products and services) in a variety of forms targeted at meeting user requirements.

6.2 • NATIONAL HYDROLOGICAL SERVICES USERS GROUP

There are many challenges to modernizing hydrological services to meet user needs. A coordination mechanism between users is often missing. Users themselves often lack the capacity to understand and leverage the benefits of hydrological services. Users and hydrological service providers communicate ineffectively. Hydrological services suffer limited capacity, and chronic underfunding inhibits sustainable hydrological services. A collaborative process between and among users and hydrological services providers best resolves the modernization challenges.

A targeted user-interaction mechanism such as a National Hydrological Services Users Group (NHSUG) provides a platform to help resolve challenges. A NHSUG is a national platform for continuous coordination, collaboration, and dialogue between providers and users of hydrological services. It facilitates joint development and implementation of mechanisms to strengthen and modernize the Hydrological Services. And by so doing, the NHSUG helps sustainably meet the users' data and information needs.

A NHSUG helps provide direction for building the HSs' capacity. It can guide the users of its products and services and related service providers to be more effective stewards of water resources and disaster risk management. Gender balance should be taken into consideration when establishing the NHSUG.

To be relevant and effective, the NHSUG needs to be fine tuned at the country level and needs to:

- Establish a coordination platform between the hydrological service providers and diverse users/sectors to support modernization, effectiveness, and sustainability of the hydrological services.
- Support users to identify their respective data, product, and service needs, while supporting HSs to understand these needs.
- Support coordination between users to improve efficiency, avoid duplication of data analysis, and share information products.
- Propose HSs product improvements or new products to meet needs.
- Develop the capacity of users of hydrological products and services so they can maximize the benefits of HS data, products, and services.
- Support awareness and outreach programs targeted at decision makers and sector users to highlight the benefits of the hydrological services.
- Explore opportunities of funding from, among others, water utilities, hydropower companies, and the private sector to support financial sustainability of hydrological services.

A NHSUG should not operate in isolation. It should closely align with initiatives in the larger framework or ministry/ministries related to water resources management. For example, the NHSUG could operate under the umbrella of a National Framework for Climate Services (NFCS). The Global Framework for Climate Services identifies User Interface Platforms as a critical component of NFCSs.

> "The User Interface Platform (UIP) provides a structured means for users, researchers, and climate service providers to interact at the global, regional, and national levels to ensure that user needs for climate services are met. The objective of the UIP is to promote effective decision making in

> view of climate considerations. The need to make climate-related decisions will be the driver for providers and users to develop more useful climate information."[5]

The National Hydrological Services Users Group should be viewed as an ongoing process that takes time and requires upstream capacity building of sectoral users. Dedicated activities and budget items should be included in modernization plans to support its establishment and bring its operations to maturity.

6.3 • CONCLUSIONS

This evidence-based analysis clearly shows that the concerns of the WBG and WMO are well founded. Hydrological Services in low- and middle-income countries are struggling to provide reliable, quality-assured hydrological services to meet user demand, and thus the future prosperity and safety of their peoples are at risk. Addressing these issues will require a joint approach involving all stakeholders and targeted to ensure that all elements of the hydrological services data, information, and services chain are addressed in a sustainable and efficient way. The WBG and WMO will therefore increase their efforts to support Hydrological Services in meeting their goals and aspirations and work closely with partner organizations in implementing the processes and procedures identified in this report. Examples of such cooperation include, inter alia, the HydroHub (a WMO initiative initially financed by the Government of Switzerland in support of WHYCOS) and the High-Level Panel on Water (HLPW) and its World Water Data Initiative WWDI) related activities.

5 http://gfcs.wmo.int/UIP

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