WORLD METEOROLOGICAL ORGANIZATION

INNITIAL PLANNING MEETING OF THE WMO GLOBAL HYDROLOGICAL STATUS AND OUTLOOK SYSTEM (HydroSOS)

Entebbe, Republic of Uganda
26 to 28 September 2017

FINAL REPORT
November 2017

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1. OPENING OF THE MEETING

1.1 The initial planning meeting of the WMO Global Hydrological Status and Outlook System (HydroSOS) was held in Entebbe, Republic of Uganda, from 26 to 28 September 2017.

1.2 The meeting was opened at 09:00 on Tuesday 26 September 2017 at the Laico Lake Victoria Hotel, Entebbe, Republic of Uganda.

1.3 Mr Nebert Wobusobozi, Hydrological Adviser to the Permanent Representative of Uganda with WMO and Assistant Commissioner, Department of Water Resource Management, Ministry of Water and Environment, welcomed participants.

1.4 Mr Festus Luboyera, Permanent Representative of Uganda with WMO and Executive Director of Uganda National Meteorological Authority, welcomed participants to the Republic of Uganda. He noted the challenges Lake Victoria Basin is facing, including but not limited to forest, wetlands and ecosystems. He emphasized that knowledge is generally available, but the system to use efficiently this knowledge in decision making is largely missing. He urged participants to move forward with HydroSOS and was supportive of the Lake Victoria basin regional pilot.

1.5 Mr Paul Pilon, WMO Secretariat, thanked the Republic of Uganda for hosting the initial planning meeting of the HydroSOS, and welcomed everyone on behalf of the Secretary-General WMO, Mr Petteri Taalas. He noted that conclusions of this meeting are an important outcome to be presented at the WMO Global Conference on "Prosperity through Hydrological Services" to be held in Geneva, May 7-9 2018.

1.6 Mr Harry Lins, President of the WMO Commission of Hydrology (CHy) welcomed participants and noted that the HydroSOS is a most ambitious activity, and together with the newly established WMO HydroHub (Global Hydrometry Support Facility) and the WHOS (WMO Hydrological Observing System) when combined, are a potential game changer for hydrology.

1.7 Mr Nebert Wobusobizi apologized on behalf of Florence Grace Adongo, Director for Water Resources Management of the Ministry of Water and Environment of Uganda, for not being able to attend the meeting.

1.8 Mr Festus Luboyera, on behalf of Minister of State for Water and Environment of Uganda (Hon. Mary Goretti Kitutu), noted that access to freshwater is not only a fundamental human right, but also forms the basis for development. He recalled that climate change is real and happening now, and that Africa will be greatly impacted upon by it. He noted that Uganda is missing methodologies to develop outlook tools for seasonal predictions. Thus, Uganda would greatly benefit from the HydroSOS initiative, especially having one of the two regional pilot projects on Lake Victoria Basin, and he emphasized that the Minister wished to express her thanks to the Commission for Hydrology for conceiving and in undertaking this initiative. In addition to the expected scientific results and enhanced capabilities that will be achieved through this initiative, Mr Luboyera underlined the importance that this initiative would have in helping to strengthen collaboration among the Countries as "water does not adhere to national boundaries".

2. ADOPTION OF THE AGENDA

2.1 The participants discussed the agenda and adopted it (**Annex 1**). It was noted that all presentations and other material presented at the meeting, such as rapporteur reports, will be made available on the dedicated webpage: WMO_HydroSOS.

3. BRIEF INTRODUCTION OF PARTICIPANTS

3.1 The meeting was attended by 46 participants from 18 countries. The list of participants is given in **Annex 2** to this report.

4. INTRODUCTION TO THE WMO HydroSOS

4.1 Mr Alan Jenkins, Deputy Director and Water and Pollution Science Director, Centre for Ecology and Hydrology, and lead of the HydroSOS project on behalf of the CHy, recalled that Resolution 8 (CHy-15) was on the Development of a Pilot WMO Global Hydrological Status and Outlook System (HydroSOS). This resolution approved the formation of an expert task team to oversee the pilot phase of the initiative and report the findings to the Commission at its sixteenth session, which is expected 3 years from now.

4.2 He emphasized that HydroSOS should take advantage of existing projects such as the US Water Watch, the Australian status and streamflow forecast system, the UK Hydrological Summary and Outlook or the West African Hydrometeorological Forecasts. It is envisaged that HydroSOS would produce a status or “nowcast” (near real time hydrological information) and a 1 to 3 month outlook. The ambition is to develop a WMO capability to assess an indication of the current global hydrological status including river flow, groundwater and soil moisture, and to assess significant differences of their current and projected conditions from their normal condition. The outlook would likely take advantage of ensemble approaches to detect worsening or improving hydrological situations.

4.3 Mr Jenkins indicated that the targeted users would primarily be National Meteorological and Hydrological Services (NMHSs), but also basin managers, funding institutions, aid agencies and UN bodies. HydroSOS would not be just another system, but would bring together existing tools and approaches to develop composite products of status and outlook. It is also anticipated that global model outputs will feed regional/national/basin scale assessments within this system.

5. THE WMO CONTEXT - CHY’S ACTIVITIES AND CURRENT OPERATIONAL CAPABILITIES

5.1 Mr Harry Lins recalled that CHy activities are aligned with WMO priorities, namely: Disaster Risk Reduction, the Global Framework for Climate Services (GFCS), the WMO Integrated Global Observing System (WIGOS), and Capacity Development. CHy Members are represented in all of these major activities, and hydrology is an important aspect of

them. Efforts in hydrology are undertaken by Regional Associations particularly through their Working Groups on Hydrology, with strong linkages between them and CHy.

5.2 He indicated visually that HydroSOS was at the centre of CHy activities, linking to the WMO Flood Forecasting Initiative (FFI), the HydroHub-WHOS initiatives, the WMO Global Data-Processing and Forecasting System (GDPFS) and Disaster Risk Reduction (DRR). He further emphasized the important role that the HydroHub has in improving the hydrological observations with innovative approaches as a support to World Hydrological Cycle Observing System (WHYCOS) projects, underpinning the need for quality data to feed the end-to-end chain resulting in sound decision making. He also noted the challenge on making hydrological data available and accessible to everyone.

6. BUILDING COMMON UNDERSTANDING, REQUIREMENTS AND COLLABORATION FOR HydroSOS

6.1 Mr Harry Dixon, Group Leader, Water Resource Assessment, Centre for Ecology and Hydrology and member of the CHy Advisory Working Group (AWG), expressed that the intent of this session was to bring forward ideas and comments from the audience on participants ”wishes” (what they would like to see coming from HydroSOS) and potential challenges for their delivery. Participants spent time writing down 4-5 ideas on post-it notes and sticking these to two panels set-up for that purpose.

6.2 Mr Alan Jenkins having briefly scanned the participants’ input highlighted the main results. He noted that the key sectors from the wish list were water resource management, agriculture, and the environment, without forgetting urban areas. He noted that the time-scale and spatial resolution of products might be different from one sector to the other. He commented that one of the main challenges will be open and accessible data. A further challenge will be in ensuring NMHSs will have sufficient staff to deliver the required services. He noted that these are especially important points given that NMHSs will be highly involved in the project and will have ownership of it.

6.3 A more thorough analysis of the results of participants’ views is presented in Section 15, as additional time was needed to more thoroughly review all the material contributed during this session.

7. LESSONS LEARNED FROM EXISTING NATIONAL AND REGIONAL SYSTEMS

7.1 Mr Harry Lins provided a brief presentation on the North American Water Watch. He explained that this product was the origin of the principle of WHOS, as a best practice example for accessing streamflow data including cataloguing, metadata and data services. He identified that broadening the application beyond the North American example required an ability to systematically and frequently obtain and use other Members’ data as well as to obtain commitment from all partners.

7.2 Mr Narendra Tuteja, Manager at the Water Forecasting Services, Australian Bureau of Meteorology (BoM) and member of the CHy AWG gave a brief presentation on the

Operational Hydrological Status and Streamflow Forecast Services in Australia. He emphasized that the focus should be set on “must have” products and that efforts are needed to ensure close connexions are made and maintained with users. He noted the importance of having consistency in the data provided, research prioritisation and efforts required to transition fit for purpose research into operations and hydrological service delivery systems.

7.3 Mr Aris Georgakakos, Professor and Director of the Georgia Water Resources Institute (US) presented on the Global Flash Flood Guidance System (FFGS) on behalf of the Hydrologic Research Center. He noted that over 50 countries have implemented or are in the process of implementing this system. He outlined the underlying structure and processes of the system and some of its products that could well serve as contributions to the HydroSOS, such as its soil moisture index. Other products such as current mean areal basin precipitation and forecasted mean areal precipitation should also help assess other desired basin conditions. He noted that the FFGS is used by the NMHSs for issuing warnings of possible flash floods. He also indicated that additional functionality and testing is underway of extending the utility of the FFGS to include landslide susceptibility, riverine forecasting and urban flash flood forecasting, along with the ability to view ensemble results.

7.4 Mr Guna Paudyal, who is an Independent Consultant (Nepal), presented on efforts associated with the Hindu Kush Himalayan Hydrological Cycle Observing System (HKH-HYCOS) project. He noted that this project already has in place a Regional Flood Information System that in essence is based on a hydrological forecast system that could help form the basis for the HydroSOS pilot for South Asia should the pilot area be coincident with the modelled HKH-HYCOS area. He indicated that participants in this project have recognized the benefits of strengthening their observation systems and have actively shared data and information. He concluded that when countries see the benefits of such projects, it encourages them to share their data and to further advance their observing and forecast systems.

7.5 Mr Mohammed Hassan, IGAD Climate Prediction & Applications Centre (ICPAC, Kenya) presented the Provision of ICPAC's East African seasonal bulletins and outlooks. He emphasized the issue of insufficient data and the difficulty of sharing them among countries. He noted that tailoring climate services to specific needs is also rather challenging, as more information is need to do so. He further noted that the probabilistic nature of climate and hydrology and the importance of such products to reflect this. However, he cautioned that special efforts are needed as ICPAC has been witnessing a low uptake in their use by the water sector. He opined that this was primarily due to an inability of users to interpret them.

8. STAKEHOLDER NEEDS

8.1 Mr Sowed Sewagudde, who is Principal Water Officer of Uganda’s Ministry of Water and Environment, presented on the perspective from Lake Victoria Environmental Management Project. He also presented on the related Water Information System and efforts being undertaken to build a one-stop water and environmental information and knowledge centre. He expressed the clear need of capacity development. He also noted that the building of consensus at the region level is a challenge, but is important in allowing progress to be achieved. He finally noted that the Lake Victoria Basin Commission, although still young, is willing to support the HydroSOS.

8.2 Mr Saiful Hossain, Superintending Engineer of the Bangladesh Water Development Board and Hydrological Adviser to the Permanent Representative of Bangladesh with WMO, presented on the perspective from Bangladesh. He emphasized that Bangladesh is frequently flooded, with about 22% of the country being flooded every year and rising up to 66% during extreme events. He indicated that the priority should focus on resilience based on improved forecasting systems. He indicated the need to have new products having "reasonable accuracy" to complement those already produced by the NHS, such as flash flood warnings, increased flood forecast lead times from 3 days outward to seasonal, and drought predictions. He noted that there is large need for these based on user demands. He also noted that when addressing challenges, we must be inclusive, global and participatory.

8.3 A summary of these two presentations and the resulting discussions can be found in the rapporteurs report for this session on the WMO website for the meeting, which is provided in Section 2.1 of this report.

9. STATUS AND OUTLOOK SYSTEM: DATA SOURCES AND EXCHANGE METHODS

9.1. Mr Hyungjun Kim, Associate Professor, University of Tokyo, Japan, presented the on-going efforts to develop and make available products from the GSMaP (Global Satellite Mapping of Precipitation) initiative. He provided an overview of products available globally, and their resolution, potential accuracy and latency.

9.2 Three breakout groups addressed questions related to required climate, meteorological, hydrological and geospatial data, collate and sharing mechanisms, uncertainties and quality assurance (full list of questions available in the agenda -**Annex 1**-). The presentation and full results of discussions can be found in the breakout group reports on the WMO website for the meeting, which is provided in Section 2.1 of this report. A brief summary of the discussion follows.

9.3 It has been noted that a full definition of requirement for data sources and their exchange for HydroSOS is difficult to do at this stage, as the HydroSOS vision, being a community undertaking, is a "work in progress" not having yet been fully articulated and agreed upon.

9.4 Required data would likely be: precipitation, temperature, evaporation, wind speed, sunshine, radiation, streamflow discharge, water level, groundwater (level, well discharge), soil moisture, snow and ice, water diversions, lakes and reservoirs levels – including their operations, which can be very difficult to obtain. It should be noted that some of these data are a "must", while others can be considered as "nice to have". Most data would be needed at a daily time scale, with frequency depending on the specific product. For example, in the first 10 days of the outlook, processes might be modelled at sub-daily timescales requiring finer temporal resolution of the data, with such resolution possibly changing as the led time extends coincident with modelling approaches.

9.5 Data sources are primarily in situ observations maintained and obtained by NMHSs. A number of NMHSs have shared their historical data with global data centres, such as

GPCC and GRDC. Data from such centres can be accessed through websites and ftp or there might be the need to provide specific request for data, for example, to the GRDC due to sharing restrictions placed on the data by the contributing NMHSs. It was noted that in some countries, data may be available in paper format only. Special efforts are needed to make these data available electronically in digital format, through possible data rescue efforts supported by WMO.

9.6 The need for geospatial data was emphasized including, for example, digital terrain models, land use, river cross sections and soil maps. It was noted that there is a need as well for standardizing formats for gridded data and the associated metadata to facilitate their sharing.

9.7 It was thought that one approach for building regional and global status and outlook products would be through the exchange and aggregation of local/basin to national to transboundary basin established products. This could be termed a “bottom-up” approach, but may still use “top-down” meteorological and climatological products generated at the national to regional to global scale. It was noted that solutions may vary from one Country to the other, and that not every Country may be willing to share its data regardless of (WMO) Congress Resolutions 25, 40 and 60.

9.8 It was also noted that only a small number of national sites are available on the WMO Global Telecommunication System (GTS). Metadata on data quality and format need additional attention. In many cases, data are coming from different sources beyond the GTS, including various HYCOS projects, as well as model outputs and remote sensing. Participants felt that data format should be based on the WMO-OGC WaterML 2.0, and stored in a simple repository. Participants expressed the wish to benefit from other WMO programmes, based on the requirements from HydroSOS.

9.10 It was noted that a specific and dedicated effort would be needed to identify possible contributors to engage them in the HydroSOS initiative. It was envisaged that an MOU between Countries and WMO could be envisioned for delivery of the system. It was mentioned that showing benefits of data sharing could be a good incentive for having other Members remove their restrictive data policies. It was felt important that NMHSs be highly involved in the initiative from the beginning. Specific requests for data must be carefully considered, as asking for complete time series might be sensitive let alone technically difficult to meet. It has been reinforced that HydroSOS should clearly define its products and demonstrate potential benefits generated (e.g., saving lives, increased services to society, improved water resources management, economic development, and environmental protection)

9.11 Data quality and their uncertainties should be dealt with using existing best practices (recommended practices and procedures) and by adoption of WMO’s Quality Management Framework-Hydrology and WMO’s Quality Management System. A possible norm for HydroSOS data should be considered, using a simple qualitative quality assessment (e.g., poor, fair and high quality).

10. STATUS AND OUTLOOK SYSTEM: CURRENT STATUS ASSESSMENT AND MODELLING METHODS

10.1 Mr David Robertson, Principal Research Scientist in Water Forecasting, CSIRO (Australia), provided a brief presentation on recent advances in hydrological process and error modelling methods for river basin scale prediction and forecasting. He provided examples of how these advances were being used operationally in Australia allowing provision of advanced products to a broad range of users through services of the Australian Bureau of Meteorology.

10.2 Three breakout groups addressed questions related to possible existing or new modelling methods and criteria for identifying the most appropriate ones (full list of questions available in the agenda -**Annex 1**-). The presentation and full results of discussions can be found in the breakout group reports on the WMO website for the meeting, which is provided in Section 2.1 of this report. A brief summary of the discussion follows.

10.3 The discussions indicated that although data assimilation was very important and even crucial to improving model and forecast performance, it remains a topic of research in hydrological modelling and is certainly beyond our abilities to include it as part of the initial HydroSOS capacities. Appropriate time and space scales must be considered in providing users an array of much needed products. A way to filter ensemble models should also be established, given the importance of this approach to assessing uncertainty of products. Uncertainties must be incorporated from the beginning, and the methods used to estimate them should be reliable, robust and accurately reflect the true uncertainty. Observed data must be used as much as possible, and possibly combined with available, reliable remotely sensed information.

10.4 It was noted that different models are required depending on the application and availability of information: physical models, process models and conceptual models versus water balance models. Models should reflect human interventions that impact streamflow, soil moisture and ground water levels (e.g., reservoir operations and diversions). Considering the complexity of the processes involved, and that exact solutions are elusive, e.g., for ground water levels and soil moisture, lower complexity model could be useful, using indicators and simple rules, based on the example of the US drought observatory. Statistical models should be considered as well, supported by agreement between experts. The models could be coarser for longer-term drought outlooks and more accurate for short to medium-term flood and water availability forecasts, as an illustration of the complexity needed. Regardless, the system must produce outputs that are locally useful. It was stressed that user needs must drive product requirements, which, in turn, must drive model specifications.

10.5 Participants expressed that the HydroSOS pilot should dedicate time to testing the suitability and accuracy of different models. It was noted that the Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP), a project which compared various large-scale models, could help identifying potentially appropriate model, depending on the intended application and user needs. It was also felt that the HEPEX test-bed may be considered as a good example of how to investigate and compare different modelling approaches.

10.6 It was emphasized that a further mandatory requirement for model consideration within the HydroSOS is that it would have to be open source, and it would also have to be very well documented for capacity building and training purposes. Participating models supported by a community of practice was envisioned as very beneficial to advance the utility of HydroSOS.

11. STATUS AND OUTLOOK SYSTEM: HYDROLOGICAL FORECASTS AND MODELLING METHODS

11.1 Mr Jafet Andersson, who is a Research Fellow with the Swedish Meteorological and Hydrological Institute, provided a brief presentation. It focused on challenges and opportunities in the use of hydrological modelling to provide status and outlook information based on the experiences garnered from the application of the HYPE model to different countries, large transboundary river basins, regions and worldwide.

11.2 Mr Andersson provided a number of suggestions on how the HydroSOS should be approached from the use of multiple hydrological models, how to evaluate the models, on use of data including their assimilation, and the need for different communities from developers to producers to users. He also enforced the strong need for NMHSs to be involved particularly in providing feedback and input on testing products and information within their countries and providing suggestions for improvements to the system including product requirements. He noted that SMHI would like to participate in the HydroSOS initiative with its experience, operational production system, and communication platforms. His presentation and the full results of discussions can be found in the breakout group reports on the WMO website for the meeting, which is provided in Section 2.1 of this report. A brief summary of the discussion follows.

11.3 The breakout groups had been asked to consider a number of questions in their discussions, with these being given in the agenda (**Annex 1**). The participants noted that in order to identify numerical weather prediction (NWP) and climate data streams that could potentially be used in HydroSOS, that these would have to reflect the modelling approaches that would, in turn, be based on user requirements and the limits of science to meet these needs. Participants noted that regionally and locally available NWP results should be used. Participants also developed a number of criteria on establishing the suitability of data streams. One important consideration was given to operational readiness, suitability and timeliness for use in hydrological models.

11.4 Participants noted that purpose (user needs) must drive selection of modelling approaches, which is also dependent on data availability and their scales. It was noted that post processing of NWP and climate streams (e.g., satellite and/or gauged data) must be undertaken to remove systematic and biased estimates of quantitative precipitation estimates and forecasts, prior to being used in hydrological models. It was felt that the full suite of possible models from hydrological process, routing and statistical models could be considered as needed. It was noted that *WMO Guidelines on Seasonal Hydrological Prediction* document contains a lot of relevant information that could be used as a starting point for forecasting methods at the sub-seasonal to seasonal time scales (currently under peer review).

11.5 Participants felt that the choice of temporal and spatial scales for modelling should reflect user needs, but also depended on data availability. As well, the hydrological modelling system must adequately represent the different hydrological processes to address user requirements. It was noted that temporal and possibly spatial scales may vary as one moves along the forecast horizon from 0 to 10 days versus 10 to 30 days or beyond to 3 months. It was also noted that the suitability of such forecasts should be assessed

based on a number of approaches ranging from cross validation techniques to the extent to which the purpose was served.

11.6 Participants also felt that HydroSOS should use multiple forecasting techniques and simulations. In doing so, use of common model output formats, such as NETCDF, will facilitate this. As well, it was noted that criteria must be developed and used to filter model sources and their results based on forecast skill, such that not all results are necessarily treated equally likely.

12. STATUS AND OUTLOOK SYSTEM: IT INFRASTRUCTURE AND SYSTEMS DEVELOPMENT

12.1 Mr Andy Wood, who is Project Scientist at the National Center for Atmospheric Research (NCAR, USA), gave an overview on the trade-offs and science in hydrological monitoring and prediction systems. His presentation provided a number of interesting points to consider in the design of the system. His presentation and the full results of discussions can be found in the breakout group reports on the WMO website for the meeting, which is provided in Section 2.1 of this report. A brief summary of the discussion follows.

12.2 The three breakout groups addressed questions related to interacting with existing IT infrastructure, open source technologies, development, maintenance and licensing costs for such systems, required IT infrastructure and specifications for the HydroSOS at global, region and national scales, sustainable data sharing and relation with existing national services (full list of questions available in the agenda -**Annex 1**-).

12.3 The participants felt that deployed systems must be open source and based as much as possible on existing infrastructures, knowing that concerns might be raised by private partners. The internet is seen as being an important IT component, especially for data collection and sharing. Two different system designs could be envisioned: one being centralized and another being localized and distributed. The advantage of the former is that overall it is less expensive to build and requires less computer resources. The advantage of the second is that it takes advantage of development and products from multiple centres that could not be replicated in a centralized model. Possibly a hybrid might be an attractive solution.

12.4 Data sharing has been identified as being very challenging. Participants agreed on the importance of showing benefits of such data sharing, particularly efforts that could help build trust and arouse enthusiasm.

12.5 As HydroSOS must aim at enabling partners developing hydrological services, all stakeholders, especially NMHSs, must be involved from the very beginning and designate a lead agency for HydroSOS. HydroSOS must be transparent on what is achieved or not in order to build trust both within the producer community and with users.

13. OVERVIEW OF PILOT PROJECTS

13.1 Mr Paul Pilon, WMO Secretariat, introduced this session and provided a brief presentation on the principles underpinning the HydroSOS for the global system, the pilot projects and participating Members in the pilot projects. This session also had three presentations on the three pilots envisaged under the pilot phase of HydroSOS.

13.2 The first presentation was given by Ms Eleanor Blyth, who is a Land Surface Modeller with the Centre for Ecology and Hydrology (CEH), United Kingdom. She provided her thoughts on how global modelling could contribute to the project from a top-down approach to a bottom-up approach. She also highlighted the importance of dealing with uncertainty within the overall system design.

13.3 The second presentation was given by Mr Maximo Twinomuhangi, who is a Senior Water Officer with the Ministry of Water and Environment, Uganda, on the proposed Lake Victoria basin pilot. He provided a brief summary of the basin characteristics, issues that are facing the basin, current activities that are underway, some gaps that need to be addressed, some views on the requirements of the HydroSOS for the pilot basin, and an overview of those who might be able to contribute to the pilot.

13.4 The third and final introductory presentation was given by Mr Shared Jain, who is the Director of the National Institute of Hydrology, India. He presented on efforts that have been undertaken on hydrological modelling of the Narmada Basin using the Global Water Availability Assessment (GWAVA) model. He noted that various results could provide insights on how best to approach modelling within the pilot basins.

13.5 These four introductory presentations were followed by two parallel sessions, namely “A – What should HydroSOS aim to develop in the Pilot Projects?” and “B- Planning the Pilot Projects”, with both being given a number of questions to help focus discussions. Each of these sessions was broken into three groups under the topics of: Global Assessments Pilot Project; Lake Victoria Pilot Project; and South Asia Pilot Project. The presentations and results of discussions can be found in the breakout reports on the WMO website for the meeting, which is provided in Section 2.1 of this report. A brief summary of the discussion of the three project-oriented breakout groups follows.

14. PARALLEL SESSIONS A – WHAT SHOULD HydroSOS AIM TO DEVELOP IN THE PILOT PROJECTS AND B – PLANNING THE PILOT PROJECTS

14.1 Global Assessments Pilot Project

14.1.1 It was agreed that the goal of the global assessment pilot is to evaluate the added value of a global coordinated hydrological assessment, to assess the feasibility of the project and to verify the commitment of NMHSs. Identified benefits are notably:

- A global coverage to provide inclusive, standardized and quality information especially for countries that do not have such information. The focus will be

essentially medium to long-term (extended range) forecasting. This coverage will not replace the products of NMHS, but will leverage them.
- To improve the awareness of critical situations and to increase the visibility of the NMHS through successful products and outcomes. The pilot project should offer the opportunity to generate new momentum, to foster dialogue between different agencies and to demonstrate added value from the HydroSOS.
- To provide a comparison tool among areas using common standards.

14.1.2 The global pilot should be a demonstrator of added value of global hydrological status with involvement of all major actors. It was felt that the key users for the global pilot could be international users (UN agencies, World Bank, NGOs, …) needing a vision of status and outlooks at the global level. It was also felt that NMHSs that are lacking a forecast and warning system would also benefit from the global project. A dialogue between developers and users will be required, products should be co-designed with decisions makers, e.g., for Water-Energy-Food nexus.

14.1.3 Some existing global systems were mentioned, such as : GLDAS, NLDAS, GLOFAS, GLOFIS, WWHYPE, but others should be identified, as a global overview is missing. It was suggested that a possible HydroSOS activity could be to provide an inventory and assessment as follows:
- Synthesize and visualize existing appropriate models, establish guidelines and protocols for benchmarking, assessing uncertainty and outlining the limitations of currently available products.
- Identify which models could be part of an ensemble modelling system.
- Identify which variables should be considered, with a listing of related available datasets.
- Define a useful and realistic timeframe.

14.1.4 Possible additional pilot projects must be representative of different geomorphological, climatic and socio-economic conditions. Having both data-rich and data-poor regions would be a key as well to help assess the system's capabilities across a range of data conditions.

14.1.5 Potential risks were identified related to potentially high expectations on product reliability. Dialogue and training will be required to understand the use and limitations of the system and its products. Another obvious risk is related to contradictory results between national and global status and outlooks. It will be important to ensure ownership to partner agencies. International river basins authorities could be very supportive of the initiative and help contribute to its development and testing.

14.1.6 Various sub-tasks have been identified to reflect better hydrological conditions within the global modelling system and to raise its profile. These include: incorporation of river systems, lakes and reservoir management practices, inclusion of groundwater, communications and outreach, and creation of examples with visualization as teasers of future potential products.

14.1.7 Planning and governance of HydroSOS were also briefly addressed. It was agreed that regional meetings should occur in the first year. A possible timetable could be:
- year 1: inventory of what can be delivered and design feedback mechanism; identifying funding mechanisms; develop a demonstration system; engage modellers.

- year 2: develop an outreach mechanism; link with existing capacity building mechanisms to reach out; revise the demonstration (web site dissemination procedure plus product types).
- year 3: lessons learnt, road map for sustainable activities; user requirement product list.
- end year 3: achieve deliverables.

14.1.8 The group responded to the questions specified in the agenda. Please see the presentation “Feedback from parallel sessions: proposed global pilot” on the WMO website to view the answers provided.

14.2 Lake Victoria Pilot Project

14.2.1 One of the key points raised in the Lake Victoria basin pilot discussions was the need to engage users and stakeholders to decide which products would be most useful and needed from the system. As a result, it was identified that a stakeholder consultation process should be conducted as a first activity for the pilot project.

14.2.2 Another key element of the discussions was the need of national buy-in for the project by all of the involved countries. Among the recommendations to achieve this were: commitment from politicians and policy makers should be sought; policy papers should be drafted to target politicians and high level stakeholders; and a clear link with the Sustainable Development Goals (SDGs) agenda should be establish so as to give a more robust foundation for the political uptake of the project.

14.2.3 Another important aspect was identified during the discussions. It was that a mechanism should be identified that will allow the institutionalization of the system to ensure commitment from the countries and sustainability in the long term. This was thought to be critical to ensure that there is “political memory” for the project and that even if the counterparts contributing to the project in each country leave their duties, the subsequent person or group will be aware of the system and would be able to continue to contribute to and use the system.

14.2.4 Finally, it was recommended that a Regional Centre (RC) be formed or appointed in order to serve as a hub for data exchange, local modelling efforts, and to provide inputs to the different products that will be needed both locally and from the global system. The boundaries between the RC and each NMHS should be clearly defined. Two possible regional entities were identified that may be willing and able to host it. One was the IGAD Climate Prediction and Applications Centre (ICPAC) and the second was the Lake Victoria Basin Commission (LVBC). Moreover, discussions ensued about the establishment of an Institute of Hydroclimatology in the region.

14.2.5 The group identified that a Concept Note is needed in the immediate future to start creating interest and attain funding to the LVB Pilot Project within HydroSOS.

14.2.5 The group responded to the questions specified in the agenda. Please see the presentation “Feedback from parallel sessions: proposed Lake Victoria pilot” on the WMO website to view the answers provided.

14.3 South Asia Pilot Project

14.3.1 The breakout group reported that it felt that the South Asia basin pilot area should be similar to that modelled within the HKH-HYCOS project for the Ganges, Brahmaputra and Meghna river basins. Factors leading to this recommended target area was that it was transboundary, had extremely large vulnerable populations to water stressors, had significant cryosphere components, had existing modelling efforts underway, and had significant economic and social benefits that would result should HydroSOS be successful.

14.3.2 It was noted that there were existing modelling efforts covering the target area. The South Asia Flash Flood Guidance System is already being developed and could provide products to this effort, such as satellite corrected estimates of mean areal precipitation, forecasted mean areal precipitation, soil moisture, and various snow products. It was also mentioned that the Geospatial Stream Flow Model (GeoFSM) has been implemented by the USGS over this area and was said to be performing well.

14.3.3 One issue raised in the development of status and outlooks for the target area was that India, which contains a portion of the upper catchment of the Ganges River, has significant reservoirs on it, and it is very reluctant to share any river flow data for that river. The breakout group had devoted a lot of time and thought to this issue and concluded that lacking contributed data for a portion of the basin should not prevent the project from proceeding. It was felt that this situation will be faced in other transboundary basins as the HydroSOS evolves, and tackling techniques now for infilling, re-constructing data possibly using remote sensing, would be valuable for other applications. It was recognized that it is a country's right not to participate fully or at all in a project that goes forward.

14.3.4 The breakout group also discussed the advantages of a "proof-of-concept" pilot in the South Asia region that would see the application of the methodologies on a smaller area, possibly the Godavari, Narmada or Tungabhadra basins in India. It was important that there be communalities between the proof-of-concept effort and the effort for the Ganges, Brahmaputra and Meghna river basins regarding the standardized methods and approaches to be used within the HydroSOS, and it was thought that the proof-of-concept application would help in this regard.

14.3.5 It was also stressed that the short to medium-term forecast horizon, which extends from the status to 10 days out, is extremely important to the hydrological communities and their users, as is the horizon beyond 10 days. The entire range from status through to seasonal was felt to be a key ingredient that would help make the HydroSOS products a success, as they are gravely needed in this regional area. Close collaboration with the basins' NMHSs was seen as absolutely necessary and essential for project's success. The key users would be the all agencies with responsibilities related to floods through droughts including agriculture and water resources management.

14.3.6 The breakout group also suggested that WMO needs to engage with Permanent Representatives and to directly involve the Hydrological Advisors to assist the HydroSOS, in particular, for the pilot basin applications. It was noted that the basin pilot needs to take advantage of national expertise, for example India in weather and climate forecasting and predictions and in hydrological experts from Bangladesh, India, and Nepal. It was further noted that the project would also benefit from expertise external to the basin, for example, from Australia, Italy, the UK, and the USA.

14.3.7 The group also noted the need to have agencies support data exchange and model development applications. It was also felt that financial and human resources need to be

clearly defined, and efforts must made to secure the necessary funding. It also felt that capacity building and training had to also figure prominently in the overall system design in the pilot basin.

14.3.8 The group also underlined the importance of linking closely with prime users of HydroSOS products. This would not only be NMHSs who would be providing value-added services, but also water resources managers. The agricultural community was also singled out as an important user, where products could be developed so that farmers having small land holdings could benefit from tailored products.

14.3.9 The group responded to the questions specified in the agenda. Please see the presentation "Feedback from parallel sessions: proposed South Asia pilot on the WMO website to view the answers provided.

15. CLOSING SESSION

15.1 Participant Feedback

15.1.1 Mr Harry Dixon, assisted by Ms Tanya Warnaars, who is a Scientific Project Manager & Knowledge Exchange Officer, CEH, UK, provided an overview of participants input from the first day. He thanked participants for their high degree of involvement in session on "Building common understanding, requirements and collaboration for HydroSOS", which was mentioned in Section 6 of this report. They noted that there were over 200 wishes and challenges statements that had been identified, both through participants' submissions and from discussions during the three day event. These are available on the meeting website in the document: List of Wishes and Challenges from Day 1.

15.1.1.1 The participants identified the following needs ("wishes") to be addressed:

- Inclusiveness of the System, considering stakeholders and end-users, having open dialogue, and developing a community,
- Develop end-products tailored for users/general population and should include maps and graphics,
- Support data exchange, harmonize data formats, have reliable real time, historical and human-influenced (i.e. reservoir operations) data, integrate surface and groundwater data, etc.,
- Ensure clear governance and commitment from all parties,
- Ensure sustainability of NMHSs and their capacity to deliver products,
- Need to engage with and develop products for: agricultural, health, and energy sectors, municipalities (urban areas), water authorities/water resource managers (including dams and reservoirs operators),
- Develop products at all scales (global, regional, national, basin and local).

15.1.1.2 The participants identified the following challenges for the System:

- Ensuring data availability, access and sharing (including formats and quality),
- Addressing areas with sparse or nonexistent hydrometric networks,
- Ensuring capacity of skilled workforce to help build the system and to use value-added products,
- Developing standardized approaches for use within the system and its global and basin pilots,

- Developing a Community of Practice,
- Assuring funding and sustainability of the System.

15.1.2 It was evident that there was consensus that special attention and a sizeable effort is needed to engage users early in the development of HydroSOS and throughout the pilot phase of the project. Similarly, NMHSs must be seen as being the core proponent of the system and be highly instrumental in guiding it, particularly for the basin pilots. Strong engagement and participation of both these areas is needed to assist in developing the most needed products.

15.1.3 Participants had also cautioned that products must also serve users that have low band width and poor internet capabilities. Efforts will be needed on making numerical products, graphs and maps available under such conditions.

15.1.4 Participants in the session also raised a number of additional items. These included:

- The need for developing a sound governance structure and reporting mechanism that was transparent and accessible to all.
- HydroSOS may be very useful for water resources management sector and not only NHSs.
- Some sectors may require special efforts to be engaged.
- Care must be given to be needs-driven and establishing a shared vision that can be achieved.
- Products need to be clearly defined and should not be seen to supplant but rather complement current services provided by NHSs.

15.2 Next Steps

15.2.1 Mr Alan Jenkins indicated that the immediate next step was the convening of the Task Team the very next day to discuss outcomes from this 3-day Initial Planning Meeting. Attention and effort will be needed to appoint work package leaders, with each work package having a small team. He indicated that he anticipated the expanded Task Team would meet in early 2018, possibly towards the end of February. It would be developing more detailed work plans for the project phase and will be expanding the work package descriptions.

15.2.2 Mr Jenkins also noted the importance of bringing HydroSOS and the outcomes of this meeting to the global conference being planned in Geneva next May on Prosperity through Hydrological Services. It will be an opportunity to share more broadly the aims and ambitions we have and to share some concrete thoughts on end products that could be attained through the HydroSOS pilot phase.

15.2.3 He also indicated that there would soon be a short report for this event along with all presentations and rapporteurs reports available on the WMO website. He indicated that this was an opportunity for those from NMHSs to discuss HydroSOS with their Permanent Representatives and Hydrological Advisors and to raise the potential role of yourself and your organizations in this effort.

15.2.4 Mr Jenkins also suggested that participants could contact him or Harry Dixon, copying the WMO Secretariat, if you were interested in being a work package lead or would simply like to contribute to the project, or needed any form of assistance. When so doing,

he requested that individuals also think of what national or international sources could be tapped to contribute to this initiative.

15.2.5 He concluded by stating that he was in a very positive mood from what he had witnessed over the last three days. He realized that there are some challenges to overcome, and that a longer time frame would be needed to address all the wishes/products that had been raised at the meeting. He thanked everyone for their participation and indicated that this was going to be a major initiative that would need a lot of effort.

15.3 Closing Remarks

15.3.1 Mr Amos Makarau, President of Regional Association I Africa, Director of the Meteorological Services Department, Zimbabwe, on behalf of Mr Festus Luboyera, Permanent Representative of Uganda with WMO and Executive Director of Uganda National Meteorological Authority, thanked everyone for their active participation. He stressed the need to keep the Permanent Representatives informed on this very important initiative. He also mentioned that additional effort will be needed to develop a shared vision and to garner genuine engagement of NMHSs and users. He also indicated his pleasure with Lake Victoria being one of the two basin pilots.

15.3.2 Mr Harry Lins, President of the WMO Commission of Hydrology, stated that he had rarely seen such involvement and engagement in a meeting by participants and thanked everyone for their contributions. He also noted that a concerted effort by him and Mr Makarau and others would be needed to promote these projects to WMO senior executive management. He thanked Mr Alan Jenkins, the HydroSOS Task Team, and WMO Secretariat for their efforts to make the meeting a success, and thanked Mr Tom Kanyike for his efforts on local arrangements that had been truly wonderful. He concluded by thanking the Ministry of Water and Environment of Uganda for hosting the Initial Planning Meeting of the HydroSOS.

END

ANNEX 1

WMO Global Hydrological Status and Outlook System (HydroSOS)

INITIAL PLANNING MEETING

AGENDA

26 TO 28 September 2017
Laico Hotel, Entebbe, Uganda

Tuesday 26 September

08:00 Registration opens

09:00 **Opening Ceremony** [Chair: Nebert Wobusobozi, HA Uganda]

- Welcome speech by Host Country [Festus Luboyera, PR Uganda 10 min]
- Welcome Speech by WMO [Paul Pilon 5 min]
- Welcome on behalf of Commission for Hydrology [Harry Lins 5 min]

09:20 **Adoption of the Agenda**

09:25 **Brief introduction of participants** [Chair: Paul Pilon 20 min]

09:45 **Introduction to the WMO Global Hydrological Status and Outlook System (HydroSOS)** [Alan Jenkins 30 min]

10:15 **Welcome remarks by the Director for Water Resources Management** [Florence Grace Adongo 10 min]

10:25 **Welcome address on behalf of the Minister of State for Water and Environment, Uganda, Hon. Mary Goretti Kitutu** [Festus Luboyera 10 min]

10:35 Break and group photo

11:15 **The WMO context - CHy's activities and current operational capabilities**

[Harry Lins 30 min]

11:45 **Building common understanding, requirements and collaboration for HydroSOS** [Harry Dixon 30 min]

Note to participants - For this session, each participant will be asked to provide in writing their (i) top 2-4 wishes/requests for HydroSOS (ii) top 2-4 challenges in making HydroSOS a reality. Please include your contact details if you wish to be contacted regarding your comments. The "Wish List" will be summarized during day 3.

12:15 Lunch

13:30 **Summary of main point raised in relation to understanding, requirements and collaboration for HydroSOS** [Alan Jenkins 15 min]

13:45 **Session 1: Lessons learned from existing National and Regional Systems** [Chair: Paul Pilon]

- North American Water Watch [Harry Lins, 20 min + 5 min questions]
- Operational Hydrological Status and Streamflow Forecast Services in Australia [Narendra Tuteja, 20 min + 5 min questions]
- Global Flash Flood Guidance System [Aris Georgakakos, 20 min + 5 min questions]
- Hindu Kush Himalayan Hydrological Cycle Observing System (HKH-HYCOS) [Guna Paudyal, 20 min + 5 min questions]
- Provision of ICPAC's East African seasonal bulletins and outlooks [Mohammed Hassan 20 min + 5 min questions]

15:50 Break

16:15 **Session 2: Stakeholder Needs** [Chair: Tom Kanyike]

- Perspective from Lake Victoria Environmental Management Project [Sowed Sewagudde 20 min + 10 min questions]
- Perspective from Bangladesh [Md. Saiful Hossain 20 min + 10 min questions]

17:45 Day 1 Wrap-up [Alan Jenkins 15 min]

18:00 Session adjourns

18:15 **Networking event**

Wednesday 27 September

09:00 Brief overview of Day 1 [Alan Jenkins 15 min]

09:15 Session 3: Status and Outlook System: Data Sources and Exchange Methods

[Chair: Harry Dixon and Dominique Berod]

- Development and potential use of the GSMaP: Global Satellite Mapping of Precipitation data products for large scale hydrological status and outlook assessments [Hyungjun Kim 15 min]

Note to participants - Following the presentation the meeting will split into three breakout groups to discuss the following questions:

1. *What meteorological and climatological data are going to be needed to produce the HydroSOS products, and what are the best sources?*
2. *What are the best mechanisms for us to collate the real-time and historical hydrologic data required for the HydroSOS?*
3. *What geospatial data will be required for HydroSOS, and what data are available?*
4. *What are the possible ways for sharing of data amongst HydroSOS project partners?*
5. *What methods could be used for dealing with uncertainty in data and what quality assurance procedures could be used?*

10:45 Break

11:15 Session 4: Status and Outlook System: Current Status Assessment and Modelling Methods [Chair: Harry Lins and Tom Kanyike]

- Research advances in hydrologic process and error modelling methods for river basin scale prediction and forecasting in Australia. [David Robertson 15 min]

Note to participants - Following the presentation the meeting will split into three breakout groups to discuss the following questions:

1. *How do we combine observational data with modelled 'nowcasting' fields to assess current status?*
2. *What types of modelling methods could be used in the HydroSOS system and what is the desired level of complexity of these methods?*
3. *What criteria and approaches could be used for identifying suitability of the candidate modelling methods?*

4. *What modelling tools exist and how can they be integrated into the HydroSOS System? (taking into account data types, skills and efforts required to trial them in the System)*

12:45 Lunch

14:00 **Session 5: Status and Outlook System: Hydrological Forecasts and Modelling Methods** [Chair: Eleanor Blyth and Paul Pilon]

- Challenges and opportunities in the use of hydrological modelling to provide status and outlook information – examples from Sweden, Europe, Niger River, Arctic, India, and WorldWide-HYPE. [Jafet Andersson 15 min]

Note to participants - Following the presentation the meeting will split into three breakout groups to discuss the following questions:

1. *What NWP and climate data streams (precipitation, temperature, surface and groundwater flows) could potentially be used/tested in the HydroSOS project, and what criteria could be used for identifying their suitability?*
2. *What types of hydrological forecasting methods could be used in the HydroSOS project?*
3. *What temporal and spatial scales are of interest for testing in the HydroSOS?*
4. *What criteria and approaches could be used for identifying suitability of the candidate forecasting methods?*
5. *How can the System take advantage of using multiple forecasts/simulations? Is this feasible?*

15:30 Break

16:00 **Session 6: Status and Outlook System: IT Infrastructure and Systems Development** [Chair: Narendra Tuteja and Harry Dixon]

- US/NCAR perspective on Monitoring and Prediction Systems: tradeoffs in these operating systems [Andy Wood 15 min]

Note to participants.- Following the presentation the meeting will split into three breakout groups to discuss the following questions:

1. *Does the HydroSOS need to interact with existing IT infrastructure and systems, and if so, which ones(e.g. WIGOS/WHOS) and how?*
2. *How important are issues such as open source technologies, development, maintenance and licensing costs for such systems?*

3. *How might we best establish the required IT infrastructure and specifications for the HydroSOS at global, region and national scales – what are the key constraints and opportunities?*
4. *How can sustainability and continued data sharing be assured for HydroSOS?*
5. *How could the design of HydroSOS system be influenced by the way national hydrological and meteorological services are delivered in various countries? How could we cater to the requirements where national meteorology and hydrology services are delivered through different agencies?*

17:30 Day 2 Wrap-up [Alan Jenkins 15 min]

17:45 Session adjourns

Thursday 28 September

09:00 Brief overview of Day 2 [Alan Jenkins 10 min]

09:10 **Overview of the pilot projects** [Chair: Paul Pilon]

- Introduction [Paul Pilon 10 mins]
- Overview of Proposed Global Assessments Pilot Project [Eleanor Blyth 10 min]
- Overview of Proposed Lake Victoria Pilot Project [Maximo Twinomuhangi 10 min]
- Overview of Proposed South Asia Pilot Project [Sharad Jain 10 min]

09:50 **Parallel Sessions A – What should HydroSOS aim to develop in the Pilot Projects?** [90 mins]

- Global Assessments Pilot Project [Meeting Rooms A, Chair: Eleanor Blyth]
- Lake Victoria Pilot Project [Meeting Room B, Chair: Tom Kanyike]
- South Asia Pilot Project [Meeting Room C, Chair: Narendra Tuteja]

Note to participants.- The meeting will break into the three abovementioned groups. Each group should discuss the following questions in relation to their assigned pilot project:

1. *What status and outlook information currently exists, and is it currently being used in the pilot areas?*
2. *What status and outlook products need to be developed, and who will be the key users?*
3. *What might be the high-level 'look and feel' of the HydroSOS products?*
4. *In selecting a geographical area for the pilot to focus on, what are the essential factors which need to be considered?*
5. *What are the key constraints and potential risks?*
6. *How will the institutional arrangements in the various countries will influence the design of HydroSOS? (e.g. existence of separate or combined National Meteorological Services and National Hydrological Services, Disaster Risk Reduction and Water Management Agencies, etc.)*

11:20 Break

11:45 **Parallel Sessions B – Planning the Pilot Projects** [90 mins]

- Global Assessments Pilot Project [Meeting Rooms A, Chair: Eleanor Blyth]
- Lake Victoria Pilot Project [Meeting Room B, Chair: Tom Kanyike]

- South Asia Pilot Project [Meeting Room C, Chair: Narendra Tuteja]

Note to participants - The meeting will remain in the same three group as before the break, each should discuss the following questions in relation to their assigned pilot project:

1. *What are the critical activities during the pilot phase and what is their order of priority?*
2. *What contributions or inputs can different research or operational agencies make to the demonstration pilot project?*
3. *What are realistic deliverables and timeframes for the pilot project work plan?*
4. *How do we make sure the pilots are successful and what does success look like (how do we measure success)?*
5. *What are the next steps?*

13:15 Lunch

14:30 **Session 7: Feedback from Parallel Sessions** [Chair: Paul Pilon]

- Global assessments [Rapporteur 20 min + 10 min discussion]
- Lake Victoria [Rapporteur 20 min + 10 min discussion
- South Asia [Rapporteur 20 min + 10 min discussion]

Note to participants - This summary session will allow the rapporteurs from the morning's parallel sessions provide feedback to the meeting on the each pilot project.

16:00 Break

16:30 **Closing Session**

Participant Feedback [Harry Dixon 40 min]

Note to participants - Participants will be asked to reflect on the points raised during the Day 1 "Building common understanding, requirements and collaboration for HydroSOS" session, focusing especially on stakeholder needs and engagement opportunities.

17:10 Next Steps [Alan Jenkins 10 min]

17:20 Closing Remarks [Harry Lins 10 min]

17:30 Close of Meeting

ANNEX 2

INITIAL PLANNING MEETING OF THE WMO GLOBAL HYDROLOGICAL STATUS AND OUTLOOK SYSTEM (HYDROSOS)
(Entebbe, Uganda, 26 – 28 September 2017)

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