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Initial Planning Meeting of the Southeast Asia Flash Flood Guidance System (SeAFFGS) and Joint Meeting of the SWFDP-SeA and SeAFFGS

Ha Noi, Viet Nam, 20–23 November 2017

FINAL REPORT

January 2018

Table of Contents

1. Background

In the southeast Asia region, flash floods account for a significant portion of the lives lost and property damages due to flooding. Given that flash floods can occur at any time or place with disastrous impacts, it has long been recognized that the development and implementation of a flash flood forecasting system would greatly benefit society. Accurate and timely warning of flash floods enables the mandated national authorities to undertake appropriate measures, thereby contributing to protecting the population at risk from their disastrous effects.

As part of WMO's Flood Forecasting Initiative (FFI) and on the basis of a 4-party Memorandum of Understanding signed by the World Meteorological Organization (WMO); US NOAA National Weather Service (US NWS); the Hydrologic Research Center (HRC), San Diego, USA; and U.S. Agency for International Development/Office of U.S. Foreign Disaster Assistance (USAID/OFDA), the signatories have established a cooperative initiative for the Flash Flood Guidance System (FFGS) with Global Coverage Project. To attain global coverage, specific projects are planned and conducted on a regional basis with countries that have committed in writing to participate actively in the implementation and operation of the forecast system.

The initial Mekong River Commission FFGS (MRCFFGS) became operational at MRC Regional Flood Management and Mitigation Center (RFMMC) in Phnom Penh, Cambodia in 2009. The countries involved in the MRCFFGS project include Cambodia, Lao PDR, Thailand, and Viet Nam**.** RFMMC makes available the MRCFFGS products via the internet. Every day, the RFMMC analyses the MRCFFGS outputs and provides critical system products for evaluating potential flash flood threats throughout the region on their website at http://ffw.mrcmekong.org/mrcffgs.htm.

The initial installation of the MRCFFGS pre-dates the Memorandum of Understanding (MoU) signed by the project partners, namely WMO, HRC, NOAA, and USAID/OFDA. As such, WMO had not been involved in the realization of the previous project activities. The project now is under the auspices of the 4-party partnership, and the partners in consultation with the representatives of the participating countries deemed it necessary that the system be upgraded to reflect the latest advances in product development and in the flash flood hydrometeorologist training programme to standardize and provide additional training to forecasters from the participating NMHSs. These efforts are needed to bring the MRCFFGS in line with other regional FFGS projects. These new activities are specified in the Letter of Agreement (LoA), Revision 2 and 4, Work Plans III and V. As per the work plan, first Steering Committee Meeting (SCM1) and operational training at HRC, San Diego, USA have been completed.

A contribution agreement between Environment and Climate Change Canada (ECCC) and WMO for the project entitled *Building Resilience to High-Impact Hydrometeorological Events through Strengthening Multi-Hazard Early Warning Systems (MHEWS) in Small Island Developing States (SIDS) and Southeast Asia (SeA)"* was signed on 19 February 2017. Within the scope of this project, it was envisaged to develop and implement the Southeast Asia FFGS (SeAFFGS) with advanced FFGS modules such as weather Radar precipitation and high resolution mesoscale Numerical Weather Prediction (NWP) Qualitative Precipitation Forecast (QPF) ingestion. It is aimed at NMHSs which are responsible for issuing flash flood forecasts and warnings. The SeAFFGS will be complementary to the MRCFFGS in a way in which during the development and implementation phase of the SeAFFGS, NMHSs of the participating countries will have access to the MRCFFGS products; and once the SeAFFGS becomes operational, its advanced products will be made available to MRC. Furthermore, linkage between Severe Weather Forecasting Demonstration Project for Southeast Asia (SWFDP-SeA) will create synergy for the severe weather forecasting in the region and will provide, inter alia, high resolution NWP QPF and nowcasting products to the SeAFFGS.

In this regard, three meetings were held in Ha Noi, Viet Nam from 20 to 23 November 2017, specifically i) parallel meetings of the SeAFFGS Initial Planning Meeting (IPM) and Regional Sub-project Management Team (RSMT) meeting of the SWFDP-SeA from 20 to 22 November; ii) joint meeting of the SeAFFGS and SWFDP-SeA in the morning session on 23 November; and iii) the first meeting of the Southeast Asia Project Steering Committee (SeA-PSC-1) in the afternoon session on 23 November.

The purpose of holding these meetings was to create synergies between the SWFDP-SeA and the SeAFFGS through enhancing the linkages between the two systems for providing efficient and effective severe weather and flash flood warnings. The main objectives of the RSMT meeting were to take stock of progress achieved by the SWFDP-SeA to date and discuss possibilities to move to the operational (final) phase of the project. On the other hand, the main objectives of the SeAFFGS IPM are to provide participants with a basic understanding of the fundamentals of the FFGS and explore ways for its development and implementation, including the commitments and activities that are required for the system to function properly. Finally, the purpose of the SeA-PSC-1 was to introduce the ECCC-funded project and verify, adjust and confirm its overall implementation plan and annual work plan for 2017 and 2018, of which the SWFDP-SeA and SeAFFGS activities are core elements.

2. Introduction

In the joint opening session of three meetings, deputy director of the National Hydro-meteorological Service of Viet Vam, Mr Tran Hong Thai welcomed everyone to Viet Nam and highlighted the importance of working together through regional cooperation particularly to improve early warnings of the severe weather hazards through the Southeast Severe Weather Forecasting Demonstration (SWFDP-SeA) project by sharing data and NWP products under the responsibility of the Regional Forecasting Support Centre (RFSC) in Ha Noi. He mentioned that new investments such as installation of new High Performance Computer (HPC) and high internet speed are underway to improve provision of data and products to the participating countries. He stated flash floods are amongst the deadliest natural phenomenon in the world and in the region and also cause considerable environmental and economic damages. He mentioned approximately 200 people died due to flash floods in Viet Nam in 2016 and noted that there were difficulties with the flash flood warnings due to uncertainties associated with flash flood forecasts. He stated that development and implementation of the SeAFFGS in coordination with the SWFDP-SeA is crucial to enhance national and regional flash flood forecasting capabilities of the NMHSs. He expressed his appreciation for the WMO support for various projects as part of mult-hazard early warning systems (MHEWS) in the southeast Asia region and ECCC's support for the SWFDP-SeA, SeAFFGS, and ASEAN Climate Outlook Form (ASEANCOF) projects. Finally, he wished the meetings success and indicated he was looking forward to their deliberations that he hoped would result in agreement on concrete actions leading to the development and implementation of SeAFFGS and linkage between SWFDP-SeA and SeAFFGS.

Mr Adboulaye Harou (WMO) welcomed everyone to the meeting on behalf of the Secretary-General, Mr Petteri Taalas. He stated that SWFDP-SeA was implemented at the Regional Forecast Support Centre in Ha Noi in 2011 and providing severe weather products to the participating countries, namely Cambodia, Loa PDR, Philippines, Thailand, Viet Nam in support of global producing centres. He expressed his appreciation to the National Hydro-meteorological Service of Viet Nam for its continued support. He mentioned that flash flood are amongst the deadliest hydrometeorological hazards causing five thousand deaths annually. He noted that linkage between SWFDP-SeA and SeAFFGS will create synergy between the two projects for the provision of improved severe weather warnings including flash floods. He highlighted needs for capacity building at the NMHSs in issuance timely and accurate flash flood warnings. He thanked MRC for hosting the MRCFFGS for providing FFGS data and products to the participating countries. Finally, he wished all participants successful meetings to attain beneficial outcomes.

Mr Harou described the purposes of the Sub-project Management Team (RSMT) meeting. He briefed the audience on the SWFDP project in Asia, SWFDP-SeA project implementation status, and benefits of linkage between SWFDP and FFGS projects. He also stress importance of holding there parallel meetings for better efficiency and coordination. He concluded by saying that this is the opportunity for participants to build a successful path forward for the successful implementation of the Canada CREWS SEA and SIDS project components for the benefits of the people in the region.

Mr Luther outlined objectives of the SeA-PSC-1 meeting. He highlighted that the SeA-PSC is the main decision-making body of the Project and would convene once a year to review progress with project implementation as well as the annual work plans. He stated that the main objectives of the meeting would be to i) provide an overview of the expected outcomes and components of the project as well as progress to date; ii) establish a steering mechanism for the Project and agree on its Terms of Reference (ToR); iii) discuss and approve the proposed activities included in the draft Implementation Plan (IP) in light of previously identified needs and existing national and regional strategies and plans; iv) synergize with relevant on-going projects in Southeast Asia; and v) agree on next steps until Mar 2018 as well as on a work plan until Mar 2019.

3. Organization and Reporting on the Initial Planning Meeting and Joint Meeting of the SWFDP-SeA and SeAFFGS

The IPM of the SeAFFGS was attended by representatives of National Meteorological and Hydrological Services (NMHSs) from Cambodia, Lao PDR, Thailand, and Viet Nam which constitute all the countries covered by the SeAFFGS. Other participants included representatives from WMO, MRC, HRC, and Republic of Korea. The IPM took place from 20 to 22 November 2017. The Joint meeting of the SWFDP-SeA and SeAFFGS took place during the morning session on 23 November 2017. The list of participants of the IPM is provided in Annex 1, while the annotated meeting agenda is given in Annex 2. The Project Brief and the Implementation Requirements document are attached as Annexes 3 and 4, respectively, and provide important background material for the system development and implementation.

All presentations made at the Initial Planning Meeting are available on the WMO WEB portal[1]. It is recommended that these presentations be consulted for all pertinent information contained therein.

4. Proceedings of the Initial Planning Meeting

Country Presentations

[1] The link to the report of this Initial Planning Meeting and its presentations is: http://www.wmo.int/pages/prog/hwrp/flood/ffgs.

Experts from each country provided in-depth presentations on the current situation of their national services related to flash flood issues including forecasting and warnings and their use in disaster management.

Cambodia

Mr Ryna presented an overview of the Department of Meteorology (DoM) of Cambodia. He outlined the following main points in his presentation: national capacity for the provision of flash floods warnings, weather forecasting and nowcasting, hydrometeorological network, availability of the hydrometeorological data, administrative structure, and dissemination of warnings. He stated that two kinds of flash flood early warnings are issued as such, namely localized flash floods at tributaries and transboundary flash floods. He mentioned that DoM is using global and limited area models (WRF) for weather forecasting. He stated that the current operational hydrometeorological network consists of 35 AWS, 24 synoptic, and 75 hydrological stations. It was mentioned that data transmission is performed through SMS, phone, and email. He showed locations of the hydrometeorelogical stations and explained data transmission methods. He stated that the Himawari weather satellite data and products are available for weather analysis and forecasting and nowcasting. He mentioned that C-band weather Radar is located in Phnom Penh and showed Radar images. It was stated that DoM is using the WMO Global Telecommunication System (GTS) for data exchange and that hydrological data are available in electronical medium and paper format since 2012 but meteorological data are not completely available electronically since 2012. The administrative structure of DoM was presented with its human resources being: total 43 staff with 7 weather forecasters and 7 climatologists and data officers. He concluded his presentation explaining procedures and methods.

Thailand

Ms Yavinchan gave a presentation on flash flood warning capability of the Thai Meteorological Department. She stated roles and responsibilities of the hydrometeorological division. She mentioned that there are 24 hydrometeorological and 1,178 automatic rainfall stations. She explained rainfall accumulation in 24 hours that cause flash floods in different regions of Thailand as: Northern region 55-90 mm, northeastern region 80-140 mm, central region 90-115 mm, eastern region 115-200 mm, and southern region 95 -205 mm. She also explained their flash flood watch and warning processes based on rainfall data, Antecedent Precipitation Index (API), and isohytal analysis. She stated that flash flood warnings are issued when the API exceeds certain threshold values such as 150 mm in general and 250 mm for the southern region. She mentioned the use of Artificial Neural Network (ANN) technology for river water-level forecasting. She completed her presentation showing Radar composite images.

Viet Nam

Mr Anh provided an overview of existing flash flood forecasting and warning processes of the National Hydro-meteorological Service (NHMS) of Viet Nam. He stated that there are 194 meteorological stations, 755 rain gauges, 453 hydrological stations, and 7 weather Radars. It was mentioned that at the headquarters of NHMS, there is also a weather satellite data reception and processing station. He explained the flash flood forecasting and warning process at the NHMS are based on 24-hr rainfall observations, QPF, potential flash flood map, and MRCFFGS products. He also explained use of the flash flood and landslide risk maps in flash flood forecast and warnings. He concluded his presentation articulating their flash flood waning dissemination process.

Mekong River Commission (MRC)

Mr Son provided an overview of the Mekong River Commission Flash Flood Guidance System (MRCFFGS) and its applications in preparation of flash floods warnings. He stated that development of the MRCFFGS started in 2005 and was implemented at the MRC Regional Flood Management and Mitigation Center (RFMMC) in Phnom Penh, Cambodia in 2009. He showed the current MRCFFFS forecaster console and explained its products that are: Satellite Hydro Estimator (GE); Merged Mean Areal Precipitation (MAP); Average Soil Moisture (ASM); Previous Flash Flood Guidance (FFG); Flash Flood Guidance (FFG); and Persistence Flash Flood Threat (PFFT). He stated the mandates and roles of the MRC Regional Flood Management and Mitigation Center (RFMMC). The MRCFFGS Regional Centre: i) provides its products via the internet; ii) analyses its products and provides critical products for the evaluation of flash flood threats for the region twice a day during the flood season; iii) organizes a technical meeting annually to discuss how to improve use of its products and sharing of experiences; and iv) prepares the MRCFFGS performance report. He explained the daily work flow for the preparation flash flood warnings and reports. He showed flash flood events occurred in the region and their verifications against MRC warning reports. He stated MRC has received feedback on the application of the MRCFFGS products. Feedback included: i) request RFMMC to modify its current products on the MRC WEB portal; ii) provision of improved warning for Viet Nam and Thailand at smaller scale: iii) requested international cooperation for the verification of the MRCFFGS products; iv) requested RFMMC to collaborate with national Disaster Management and Mitigation Agencies for the verification of warnings.

Regional Forecasting Support Centre (RFSC)

Mr Quang provided an overview of the SWFDP-SeA RFSC activities. He stated that global and regional deterministic and ensemble NWP products, weather satellite images, and guidance products such as heavy rainfall and strong wind are available on the dedicated SWFDP-SeA portal for the SWFDP-SeA domain. He stated that global deterministic and ensemble model products are provided by the global forecasting centres such as Japan Meteorological Agency (JMA), Deutsche Wetterdienst (DWD), and the National Center for Environmental Prediction (NCEP). He also stated that regional forecast models are WRF-ARW and COSMO in 15 km and 7 km spatial resolutions, respectively. He showed sample deterministic and ensemble products of the global models such as 24-hr rainfall accumulation, 24-hr precipitation probability maps with different thresholds. He also showed regional ensemble forecast products and EPSgram for specific geographical locations. He explained Himawari weather satellite data reception and processing stations and its products and 1-3 hours nowcasting products of the National Weather Center (NWC). He mentioned SWFDP-SeA guidance products as being heavy precipitation more than 50mm/24-hr and 100mm/24-hr, and strong wind speeds more than 30 knots over land and sea and 50 knots over sea. He explained that there are two kinds of guidance products - short range guidance products from one to two days, and medium range guidance products from 3 to 5 days. He showed and explained guidance products generated from the aforementioned models. He highlighted the main SWFDP-SeA activities in 2016 and 2017 as being the start of the demonstration phase, making the SWFDP-SeA portal available to the participating countries, installation of HimawariCast station, deployment of the IT systems into the new headquarter building, and participation of Mr Nguyen Thanh Tung in the WMO fellowship programme at ECMWF. He concluded his presentation explaining future plans as enhancement of forecasters skills and knowledge on the severe weather forecasting through training, conducting verification studies, and upgrading the High Performance Computer (HPC) for the provision of high resolution WRF-ARW and COSMO models for the southeast Asia domain.

Overview of the FFGS Products

Mr Jubach (HRC) provided an overview of the Flash Flood Guidance System. He explained definitions of flash floods and stated that FFGS is a tool for the NMHSs to develop flash flood warnings. He explained FFGS operational concept from the global and regional perspective as such in a regional project a Regional Centre is establish to provide data and products to the participating countries which will provide local data such as Radar, gauge, forecasts to the Regional Centre and issue flash flood warnings and alerts to the national authorities and the public. He stated key FFGS concept and products which are: Flash Flood Guidance (FFG), Flash Flood Threat (FFT), bankfull flow, and flash flood potential. He articulated the key components of the standard FFG system are, among others: real-time precipitation input, rainfall data processing, snow, soil model, threshold runoff model, rainfall forecasts, flash flood guidance model, and forecasters input. He depicted the standard FFG dashboard; forecaster user interface; and MRCFFGS products such as Global Hydro Estimator (GHE), Mean Areal Precipitation (MAP), Average Soil Moisture (ASM), Forecast Flash Flood Threat (FFFT), Quantitative Precipitation Forecast (QPF) of WRF model, and flash flood risk maps. He mentioned that text data are available from the FFGS user interface for further processing. He showed the static resources available in a standard FFG system such as product description files, country shape files with basin delineations, and software tools. He stated that the FFGS is a proven concept used in many regions and country applications. He indicated it provides robust operation through stable software, and it is adaptable to various regional and local conditions.

Mr Jubach presented current enhancements under development for the FFGS improved operations. He touched upon the following five major topics:

- Multi-model QPF use in the FFGS;
- Landslide Susceptibility Mapping;
- Urban Flash Flood Warning;
- Riverine Routing and Ensemble Discharge Prediction; and
- Seasonal and sub-seasonal climatological products ingestion.

Ms Graham (HRC) provided an overview of the Flash Flood Guidance System for Southeast Asia. She explained the following topics: i) floods and flash floods in perspective; ii) impacts of flooding; iii) basic meteorology of rainfall system causing flash floods; iv) basic river hydrology from a flash flooding perspective; and v) forecasting flash floods. She explained the flash flood definitions provided by the World Meteorological Organization (WMO) and the American Meteorological Society (AMS) and differences between riverine flooding and flash flooding. She pointed out devastating socio-economic impacts of flooding, effecting many sectors that impede economic growth. She stated the prominent weather patterns that cause flash flooding are: Inter Tropical Convergence Zone (ITCZ), tropical depressions, low pressure systems, tropical storms, and typhoons. She showed the standard FFG system forecaster interface for the MRCFFGS and explained its products. She also showed the MapServer interface that allows forecasters to overlay different GIS layers such as roads, cities buildings, and administrative borders on the FFGS products to indicate precise geographical locations of the catchments where possible flash flood may happen. She explained the hydrological processes for the occurrences of flash floods involving complex interaction between rainfall and catchments such as run-off, evaporation, infiltration, and groundwater. She mentioned that FFG offers a guidance to assist forecasters to issue timely and accurate warnings. She articulated the flash flood prediction process and associated FFG products such as Mean Areal Precipitation (MAP), Average Soil Moisture (ASM), and Flash Flood Guidance (FFG).

Ms Graham also provided an overview of data and information needs of the SeAFFGS. She stated that the following data and information should be provided if available, among others: digitalized stream network, digitalized country catchment boundaries data, land-use and land-cover, soul type and texture, local stream cross-section survey data streams draining

20-2000 km^2, population distribution, precipitation (hourly, daily, monthly, climatology), air temperature (hourly, daily, monthly, climatology), pan evaporation (daily, monthly, climatology), soil moisture, streamflow discharge, stream stage, radiation, wind, and humidity as well as meta data of the hydrometeorological stations. Detailed list of data requirements and data priorities are provided in Appendix B and C of Annex 4.

She stated that training was an integral part of the project, and extensive training would be provided to the participanting countries' forecasters. She showed the schematic diagram outlining the FFGS hydrometeorologist training programme, which is contained in Appendix A of Annex 4 of this report. She explained that it consists of five steps:

- Step 1 introductory regional workshop;
- Step 2 eLearning hydrometeorologist training;
- Step 3 specialized training at HRC;
- Step 4 regional operations training workshop; and
- Step 5 regional operational sustainability workshop.

She further articulated that when the training was completed, forecasters should be confident and competent to use FFGS products for flash flood forecasting and the provision of early warnings.

During the facilitated discussion, it was sated that using local data in the FFGS to calibrate model parameters are extremely important for model parameter set up and calibration effecting quality of the FFGS products directly. It was also stated that if local data are not provided, then only global data with coarse resolution could be used. The importance of the use of real-time precipitation data to bias-adjust satellite precipitation estimates was also stressed. Data requirements for the project are provided in Appendix B and C of Annex 4 of this document.

Project Management Aspects and Governance

Mr Pilon (WMO) provided an overview of the purposes of the workshop indicating that the main objective of the Flash Flood Guidance System was to build capacity of the NMHSs to help society cope with hydrometeorological hazards particularly those of flash floods. The workshop would also allow an opportunity to present and discuss the needs for flash flood forecasting in the Southeast Asia, including dissemination procedures and coordination between the National Meteorological and Hydrological Services and the Disaster Management Agencies. He provided information about WMO Flood Forecasting Initiative, stating that FFGS was in-line with the WMO Flood Forecasting Initiative objectives, and he also outlined the global FFGS implementation strategy.

He articulated the roles of WMO with respect to the development and implementation of the SeAFFG system, stating that WMO was the primary liaison with the NMHSs for the development and implementation of the project and its associated training programme. Further, the project is designed to provide support for establishing closer collaborations and coordination between NMHSs and Disasters Management Authorities and to enhance regional collaborations and cooperation.

He outlined the roles and responsibilities of NMHSs and Regional Centre in the SeAFFG project. NMHSs had the following responsibilities: to provide historical data to the project developer, HRC; to provide in-situ data to the Regional Centre; to participate in the flash flood hydrometeorological training programme; to issue flash flood warnings and disseminate them to their national Disaster Management Authority; and to cooperate with the Regional Centre on the SeAFFG system issues. Then, he cited roles and responsibilities of the Regional Centre as being: to communicate effectively with WMO, HRC and NMHSs on

SeAFFG system activities; to have computer hardware and software capabilities and good computer network connections; to monitor routinely the availability of the SeAFFGS products; and to conduct flash flood validation studies. Detailed information about roles and responsibilities of NMHSs and RC are provided in Annex 4 and Appendix A in this document.

He provided a brief overview of the organizational and managerial aspects of the project, reiterating the roles and responsibilities of the NMHSs and the Regional Centre. He then introduced the concept of a Project Steering Committee (PSC) and its composition, indicating that each participating country would be invited to be represented on it, as well as WMO, RC, HRC, MRC, Donor, and USAID/OFDA. Details of the PSC are found in Annex 5, while the implementation requirements are provided in Annex 4 of this document.

He provided a brief overview of the Canada CREWS SEA and SIDS initiative. He stated that the Government of Canada (Environment and Climate Change Canada – ECCC) has granted funds for the project entitled "*Building Resilience to High-Impact Hydrometeorological Events through Strengthening Multi-Hazard Early Warning Systems (MHEWS) in Small Island Developing States (SIDS) and Southeast Asia (SEA*). He said within the scope of this funding, a number of projects will be implemented in the Southeast Asia Region. These include, among others: i) Severe Weather Forecasting Demonstration Project-Southeast Asia (SWFDP-SeA); ii) Southeast Asia Flash Flood Guidance System (SeAFFGS); and iii) Climate Services. He explained the development and implementation phase, the transition phase and the operational phase of SeAFFGS in relation with the MRCFFGS and emphasized that SeAFFGS is a complementary system with advances beyond the MRCFFGS. He pointed out that during the development and implementation phase of the SeAFFGS, NMHSs would continue to have access to MRCFFGS products; and during the operational phase of the SeAFFGS, the MRC would havel access to SEAFFGS products.

SWFDP-SeA and SeAFFGS Linkages

Mr Pilon explained importance of linking SWFDP-SeA and SeAFFGS in providing forecasts and warnings of extreme hydrometeorological events including flash floods. He stated that such linkages will create synergies for both projects. He also stated the following benefits of the linkages and parallel implementation of these two projects:

- Provision of high resolution mesoscale NWP QPF products by the SWFDP-SeA;
- Provision of Nowcasting products by the SWFDP-SeA;
- Generating synergies for the early warning of hydrometeorological events, including flash floods;
- Enhancing user interfaces and expanding the suite of products available to forecasters; and
- Developing products and information that addresses needs of users to reduce loss of lives and livelihoods due to extreme hydrometeorological events.

Participants expressed their appreciation on the linkage and parallel implementation of both projects and stated that it will be very useful for the provision of hydrometeorological forecasts and warnings. Participants agreed on requesting the following data and products from the SWFDP-SeA project:

- Provision of 5 x5 km spatial resolution NWP QPF products up to 5 days for the entire Mekong River basin and four countries;
- Provision of 2 x2 km spatial resolution QPF products up to 48 hours for the entire Mekong River basin and four countries;
- Provision of 3-hr nowcasting of QPF from satellite and weather Radar data;

- Post processing of QPF products; and
- Views on best estimation of precipitation via data assimilation.

During the joint meeting of the SWFDP-SeA and SeAFFGS in which participants from the SeAFFGS IPM and SWFDP-SeA RSMT attended, Mr Jubach provided an overview of the SeAFFGS and its data requirements, while Mr Pilon explained the data and products requests from SWFDP-SeA as specified above.

After the facilitated discussion, the following main points were recommended:

- Participants agreed in principle to make SeAFFGS operational 24/7 in the participating countries subject to approval by the PRs;
- After the High Performance Computer (HPC) upgrade at the RFSC in Ha Noi in 2018, making available improved NWP LAM products from WRF and COSMO/ICON-LAM with 5x5 Km resolution for the Southeast Asia and 2-3 km resolution for the entire Mekong River basin and four countries will be provided;
- Strengthening and upgrading of the weather Radar network in Viet Nam in 2018 and 2019;
- Making available for potential use the local NWP LAM capacities at the NMHSs of Lao PDR and Thailand (Lao PDR will run the WRF model with 3 km resolution in the future. Thailand has already been running the WRF model with 2 km resolution for 2 days and with 6 km resolution for 3-5 days.);
- Satellite (e.g. JMA, CMA and KMA) and Radar based nowcasting products; and
- Efforts should be made to align projects activities and develop synergies with the projects funded by WB, ADB, ECCC-Canada, and USAID in the participating countries.

Limiting factors were also mentioned, including the poor radar coverage in some of the participating countries for use in mean aerial basin Quantitative Precipitation Estimation in SeAFFGS and lack of human resource and technological capacities of some NMHS, such as DoM of Cambodia and DHM of Lao PDR.

Interest of the Participating Countries

During the facilitated discussions, participants asked a number of questions about the FFGS concept, its products and system operations. After clarifications were made by HRC and WMO, all participants from the four countries indicated agreement that implementation of the SeAFFGS would be very useful for their countries particularly given the importance and value of issuing flash flood warnings. As well, such implementation was seen as being an important contribution to enhancing their national early warning capabilities and would also help foster closer regional cooperation on disaster risk reduction. Participants from Cambodia, Lao PDR, Thailand and Viet Nam indicated their interests and expressed the need to seek approval of their respective governments. To facilitate communication on a formal expression of interest in the project, a sample Letter of Commitment (LoC) is provided in Annex 6.

Participants discussed the concept and expected results of the SeAFFG project and agreed that it was consistent with the global aspect of the Flash Flood Guidance system and its regional implementation projects. The objective of the Southeast Asia Flash Flood Guidance project is to contribute towards reducing the vulnerability of the region to hydrometeorological hazards, specifically flash floods, by developing and implementing a

Flash Flood Guidance System to strengthen regional capacity to develop timely and accurate flash flood warnings.

Offer of the Regional Centre

Ms Mai from the National Hydro-meteorological Service of Viet Nam expressed the willingness of the NHMS of Viet Nam to host the Regional Centre for the SeAFFG project, saying, as well, that Viet Nam may need assistance from WMO and HRC for the implementation and operation of the system. All participants were pleased with the kind offer of Viet Nam to host the Regional Centre. Representatives of WMO and HRC ensured her of their organizations support for the successful implementation of the project.

Project Implementation Plan

Mr Pilon described the project implementation plan, showing the major tasks, milestones, and schedule. Delegates were kindly asked to send their Letter of Commitment to WMO by the 1st of April to start the implementation of the project. Delegates agreed on the project implementation plan, saying that they would do their utmost to comply with the plan. The SeAFFGS implementation plan is provided in Annex 7 of this document.

Closing of the Steering Committee Meeting

Closing remarks were made by the representatives of WMO, HRC, National Hydro-meteorological Service of Viet Nam, countries, and MRC. Thanks were also extended to all attendees for their active participation in the workshop and spirited involvement in the discussions, which contributed to the successful conclusion of the workshop.

5. Conclusions and Outcomes from the Initial Planning Meeting

1. There was agreement among participants that advances offered in **the development and implementation of the SeAFFG system** will significantly improve the capabilities of NMHSs in Southeast Asia to produce timely and accurate warnings of flash flood induced hazards, thereby contributing to disaster risk reduction by saving lives and reducing property damages.

2. Country participants agreed on participating in the development and implementation of SeAFFG project being funded through ***the Environment and Climate Change Canada*** (Canada CREWS SEA and SIDS project), with confirmation to follow after consultation with national authorities.

3. Participants agreed that SeAFFGS is an advanced complementary system to the existing MRCFFGS with the intent of using the latter to generate products and for issuance of flash flood warnings by NMHSs until the SeAFFGS becomes operational.

4. Country participants agreed that it would be greatly beneficial that NMHSs continue to have access to MRCFFGS products during the development and implementation phase of the SeAFFGS.

5. Participants agreed that the official name of this initiative will be **Southeast Asia Flash Flood Guidance (SeAFFG)** project. This name will be used in all documents and communications.

6. Country participants agreed that MRC should have access to SeAFFGS products and data once SEAFFGS becomes operational.

7. Country participants agreed that should MRC agree, the new SeAFFGS can be ported to the MRC servers making a back-up of the most advanced system in the region.

8. Workshop participants noted that the FFGS has a global aspect and that it is being implemented as a component of the WMO Flood Forecasting Initiative (WMO-FFI). The intent is that the implemented FFGS will be fully integrated into the day-to-day operational activities of the National Meteorological and Hydrological Services responsible for the provision of flash flood early warnings.

9. Participants agreed in principle on the following core elements of this regional project:

   - General concept and technical approach chosen to provide Flash Flood Guidance;
   - Roles and responsibilities of the dedicated Regional Centre and the National Meteorological and Hydrological Services for project implementation;
   - Project governance including the roles of all partners;
   - Guiding principles for the implementation of the SeAFFGS; and
   - Concept of Operations.

   All items listed above are provided in the Project Brief document, which is Annex 3, and in the Implementation Requirements document, which is Annex 4. These are also supplemented through the discussions and conclusions arising from this the Initial Planning Meeting held in Ha Noi, Viet Nam, on 20-23 November 2017.

10. With regard to the governance of the project, participants agreed on the structure and interim terms of reference of a **Project Steering Committee** (PSC) as attached as Annex 5 to this report.

11. To enable the effective functioning of the PSC, the participants agreed that participating countries should designate, through their permanent representative with WMO and after consultation with his/her hydrological advisor, ***focal points*** and ***alternates*** in serving on the PSC, with the expectation that these designates would serve throughout the duration of the project.

12. The participants agreed that once government approvals to participate in the SeAFFG project had been obtained, ***Letters of Commitment (LoC)*** of the participating countries should be signed by the permanent representatives with WMO and sent to WMO. It is proposed that wherever feasible, the letters should reach WMO not later than by the **1st April, 2018** (see draft Letter of Commitment in Annex 6).

13. Participants noted with appreciation the offer of the National Hydro-meteorological Service of **Viet Nam** to provide services as a **regional centre** for the project within the terms of reference as described in the "*Implementation Requirements*" document. The offer was discussed in detail and was accepted unanimously by all country representatives. Additional correspondence from the National Hydro-meteorological Service of **Viet Nam** will be required to confirm its offer of hosting the Regional Centre.

14. Participants recognized that **the incorporation of local data and information** are necessary to enhance system reliability, accuracy and effectiveness in the provision of flash flood early warnings. Further, Participants expressed their appreciation on the inclusion of the available weather Radar data into the SeAFFGS, emphasizing that it would improve spatial resolution of the sub-basins and accuracy of the SeFFGS products.

15. Country participants agreed that it would be beneficial to include as much data as possible for the development of the FFGS software and for the production of real-time products. WMO will work with the NMHSs to assist in policy aspects of making the above data available to the operational SeAFFG system. Representatives from Lao PDR and Cambodia stated that a request letter from WMO is needed for the provision of the local historical and real-time hydrometeorological data.

16. WMO and HRC will work with the National Hydro-meteorological Service of **Viet Nam** to assist it in establishing the functionality of the Regional Centre, to facilitate data transfer for project implementation, and to provide forecast products to participating countries.

17. With a view to a timely implementation of the project, the participants agreed to comply as much as possible with data requirements specified in Appendix B of Annex 4 such that the following data will be transferred to HRC through the regional centre, which is responsible for data exchange between the SeAFFG developer (HRC) and NMHSs:

    - Historical hydrometeorological data since May 2012 to present;
    - Soil data, vegetation cover and stream network;
    - Metadata of hydrometeorological stations; and
    - Quality controlled Digital Elevation Model (DEM) data.

18. Participants noted the data and information requirements of the project at the global, regional and local levels. Based on the presentations and discussions during the workshop, the required data, metadata and related information will be specified and documented in a Requirements Document that will be sent to all focal points by HRC together with data and information questionnaires. The feed-back information from focal points should reach the Hydrologic Research Center (HRC) and the Regional Centre respectively according to the implementation plan (Annex 7), which had been agreed upon at the Planning Workshop.

19. Participants agreed that the establishment of the system is a collaborative endeavour, based on the continuous feedback between development and testing, and between the Regional Centre and the participating countries. Participants recognized also that a successful design and reliable operation of the SeAFFG requires high quality data provided in a timely manner to the Regional Centre. The real time data of selected hydrometerological stations needs to be transferred to the Regional Centre as per the plan of implementation through WMO GTS and/or ftp services and/or other means.

20. To facilitate system implementation, it was agreed that data, metadata and related information needs to be transferred to the Regional Centre as soon as they become available within the timelines to be specified in the updated Requirements Document. The Regional Centre will establish promptly a dedicated and secured ftp server to ensure safe data transfer.

21. Participants agreed on the proposed milestones for the tentative **implementation plan** that are attached as Annex 7 to this report.

22. Participants noted that WMO, within the limitations of available resources, will provide overall project coordination and necessary support to activities that lead to the successful implementation of the project. This includes, inter alia, the development and provision of training programmes that will be undertaken by the Regional Centre, HRC and WMO.

23. Participants recommend strong and close linkages between SeAFFGS and SWFDP-SeA. and recommended the implementation of SWFDP-SeA and SeAFFGS projects in parallel. Participants also recommended that the provision of high resolution mesoscale NWP QPF and Nowcasting Quantitative Precipitation Forecast products should be made available from the SWFDP-SeA for use in SeAFFGS.

24. Participants of the joint session of the SWFDP-SeA and SeAFFGS noted that there is a great benefit for linking between the Severe Weather Forecasting Demonstration Project-Southeast Asia (SWFDP-SeA) and SeAFFG projects in the region such that two projects can be linked to exchange data and products such as Quantitative Precipitation Forecasts (QPFs) of the high resolution numerical weather prediction model to enhance flash flood early warning capabilities. It was agreed that the following data and products will be made available to the SeAFFGS:

- NWP Limited Area Model (LAM) model products (WRF and COSMO/ICON-LAM) in 5 x 5 km spatial resolution over the SeA domain and in 2-3 km resolution for the Mekong River basin after the upgrade of the High Performance Computer (HPC) at the Regional Forecasting Support Centre (RFSC) in 2018;

- Availabe weather Radar data, including expanded Radar network data of Viet Nam;

- Additional NWP LAM data from Lao PDR and Thailand that run WRF model in 3 km and 2 km resolution, respectively; and

- Available nowcasting products.

ANNEX 1

SOUTHEAST ASIA FLASH FLOOD GUIDANCE SYSTEM

INITIAL PLANNING MEETING
Ha Noi, Viet Nam, 20-23 November 2017

List of Participants

Cambodia	
Mr Oum Ryna Director Dept. of Meteorology N 364, Monivong Bldv, Phnom Penh City Cambodia	Phone: Email: Rynaoum63@gmail.com
Mr So Im Monichoth Deputy Director Dept. of Meteorology N 364, Monivong Bldv, Phnom Penh, Cambodia	Phone: Email: monichoth@gmail.com
Lao PDR	
Mr Khanmany KHOUNPHONH Director General PR Lao PDR with WMO Ministry of Natural Resources and Environment Department of Meteorology and Hydrology (DMH) Ban Akard;Avenue Souphanouvang; Sikottabong Dist. P.O Box 2903; Vientiane Lao PDR	Phone: Email: k.khanmany@gmail.com
Republic of Korea	
Seong Heon Kim 8 Phao Dai Lang, Dong Da, Hanoi Viet Nam	Phone: Email: Sdskma98@naver.com
Thailand	
Ms Sugunyanee Yavinchan Director of Weather Forecast 4353 Sukhumvit Rd., Bangna, Bangkok, Thailand	Phone: Email: Sugunyanee@hotmail.com
Viet Nam	
Hoan Nguyen NCHMF Hydrologist No 8 Phao dai lang Ha Noi city Viet Nam	Phone: +840904323284 Email: Hoankttv84@gmail.com

Hai doan NCHMF Hydrologist No 8 Phao dai lang Ha Noi city Viet Nam	Phone: +84947940668 Email: hai110684@gmail.com
Hoa Nguyen NCHMF Hydrologist No 8 Phao dai lang Ha Noi city Viet Nam	Phone: +84918351812 Email: ngochoa50v@gmail.com
Trinh Thu Phuong NCHMF No 8 Phao dai lang Ha Noi city Viet Nam	Phone: Email: Trinhphuong2010@gmail.com
Mr Nguyen Duc Anh NCHMF No 8 Phao dai lang Ha Noi city Viet Nam	Phone: Email: Ducanh12t@hotmail.com
Mr Nguyen Dang Quang Head of NWP and Remote Sensing 8 Phao Dai Lang, Dong Da, Hanoi Viet Nam	Phone: Email: Quangvnes@gmail.com
Vu Thanh Long Director of Northwest Regional Hydro-meteorological Centre 122 Dien Bien street, Son La city Viet Nam	Phone: Email: vulongkttv@gmail.com
Le Thanh Cong Science, Technology and International Cooperation Department, NHMS Viet Nam 8 Phao Dai Lang, Dong Da, Hanoi Viet Nam	Phone: Email: congthanhle@gmail.com
Nguyen Huy Phuong Viet Nam National Mekong Committee, MONRE 23, Hang Tre, Hanoi Viet Nam	Phone: Email: Huyphuongmk@gmail.com
Ms Do Quynh Hoa Science, Technology and International Cooperation Department, NHMS Viet Nam 8 Phao Dai Lang, Dong Da, Hanoi Viet Nam	Phone: Email: hoahtqt@gmail.com
Pham Thanh Binh Mid-nothern regional hydro-meteorological center Tan Dan Viet Tri Phu Tho Viet Nam	Phone: Email: ptbinh1978@gmail.com
Tang Van An North Central Regionnal Hydro- Meteorogical Center 144 Le Hong phong TPVinh Nghean Viet Nam	Phone: Email: tangandbkt@gmail.com

Nguyen Lan Huong Northeath Reaionnal Hydro- Meteorological Center No 1 Tran Tat Van Kien An Hai Phong Viet Nam	Phone: Email: lanhuongkttv@gmail.com
Le Tuan Nghia Institute of Meteorology, Hydrology & Environment No. 23/62 Nguyen Tri Thanh Street, Dong Da, Hanoi Viet Nam	**Phone:** **Email:** Le.nghia84@gmail.com
Ms Dang Thanh Mai Deputy director hydrological forecasting department National Center for Hydro_meteorological No 8. Phao Dai Lang Str. Dong Da Dist. Hanoi, Viet Nam	Phone: Email: thanhmaidang1973@gmail.com
MRC	
Ms Janejira Chuthong MRC Secretariat Chief Hydrologist Vientiane, Lao PDR	Phone: Email: janejira@mrcmekong.org
Mr Lam Hung Son MRC Secretariat Head of Regional Flood Management and Mitigation Center 576 National Road #2 Chak Angre Krom, Phnom Penh, Cambodia	Phone: Email: Son@mrcmekong.org
WMO	
Mr Paul Pilon Chief, Hydrological Forecasting and Water Resources Division World Meteorological Organization 7bis, avenue de Paix, Case Postale No. 2300, 1211 GENEVA 2 Switzerland	Phone: +41 (0) 22 730 83 58 Fax: +41 (0) 22 730 80 43 E-mail: ppilon@wmo.int
Mr Jochen Luther Canada CREWS SEA & SIDS Project Manager World Meteorological Organization Hydrological Forecasting & Water Resources Division 7bis, avenue de Paix, Case Postale No. 2300, 1211 GENEVA 2 Switzerland	Phone: + 41 (0) 22 730 83 50 Fax: +41 (0) 22 730 81 81 E-mail: jluther@wmo.int
Mr Ayhan Sayin Scientific officer World Meteorological Organization	Phone: + 41 (0) 22 730 83 31 Fax: +41 (0) 22 730 80 43 E-mail: asayin@wmo.int

Hydrological Forecasting & Water Resources Division 7bis, avenue de Paix, Case Postale No. 2300, 1211 GENEVA 2 Switzerland	
HRC	
Mr Robert Jubach Hydrological Research Centre (HRC) General Manager 11440 West Bernardo Court, Suite 375, San Diego, CA 92127, USA	Phone: +-1-858-798-9448 Fax: E-mail: rjubach@hrcwater.org
Dr Rochelle Graham Hydrological Research Centre (HRC) Meteorologist and Education Director 11440 West Bernardo Court, Suite 375, San Diego, CA 92127, USA	Phone: +-1-858-798-9448 Fax: E-mail: RGraham@hrcwater.org

ANNEX 2

Development and Implementation of
the Southeast Asia Flash Flood Guidance System (SeAFFGS)

INITIAL PANNING MEETING and JOINT MEETING OF THE SWFDP-SeA and SeAFFGS

Ha Noi, Viet Nam, 20-23 November 2017

Final Agenda

Day-1 (20 November 2017)

Joint Opening Session (SWFDP-SeA[2] and SeAFFGS and SEA-SCM) (Second floor-70 seats)

09:00–09:30 Registration
09:30–10:00 Opening of the Meetings (Viet Nam & WMO)
10:00–10:20 Purposes of the meetings (WMO)
10:20–10:30 Photo session

10:30 - 11:00 Tea Break

SEAFFGS Session (Second Floor-32 Seats)

11:00-11:15 Review of Draft Agenda and Introduction of participants (All)
11:15-11:30 Overview of the global FFGS (WMO)
11:30-11:45 Role of WMO (WMO)
11:45-12:00 Role of HRC (HRC)
12:00–12:15 Role of USAID/OFDA (USAID/OFDA)
12:15–12:30 Role of NOAA (HRC)
12:30-13:00 Overview of existing flash flood forecasting and warning infrastructures of NMHSs of Southeast Asia (Country presentations[3])

- National capacity for the provision of flash flood early warnings
- National capacity for weather forecasting and nowcasting (Global and limited Area Models, meteorological data processing and visualization software)
- Current hydrometeorological networks (number and types of meteorological and hydrological stations, Radar network, data dissemination methods, GTS reporting, databases)
- Availability of systematically observed hydrometeorological data (availability of the data, data types, digital or paper, periods of coverage) since May 2012

[2] Severe Weather Forecasting Demonstration Project-Southeast Asia

[3] Each presentation will have maximum 10 slides and will be limited to 15 minutes.

- Organizational structure and human resources (7/24 working, number of trained forecasters, forecasting department
- Collaboration with emergency management agencies other governmental and non-governmental (private sector, TV, Radio etc.) organizations
    - Brief overview of products and services provided

13:00-14:00 Lunch

14:00-14:30 Overview of existing flash flood forecasting and warning infrastructures of NMHSs of Southeast Asia (Country presentations) (Continued)

14:30-15:30 Facilitated discussion on *current* flash flood forecasting approaches in the region (All)

15:30-16:00 Tea Break

16:00-16:30 Overview of the Currently Operational MRCFFG System and its concept of operation (MRC)

- Mandate and its roles
- Products and delivery mechanism
- Clients, users and feedbacks

16:00-17:00 CREWS SeAFFGS initiative (WMO)

Day-2 (21 November 2017)

09:00-09:30 Summary of Day 1 (Chair)

09:30-10:30 Overview of the Flash Flood Guidance System (FFG) for Southeast Asia (HRC)

- Introduction to the SeAFFG system
- Background and key components
- Delineations
- Radar ingestion
- High Resolution Mesoscale SWFDP-SeA NWP QPF ingestion Nowcasting

10:30 - 11:00 Tea Break

11:00-12:00 Overview of the Flash Flood Guidance System (FFGS) for Southeast Asia – Continued (HRC)

- FFGS products
- Product use
- Map Server Interface

12:00-12:30 Data requirements for the SeAFFGS (HRC)

12:30–14:00 Lunch

14:00-15:00 Facilitated discussions on the availability and access to historical and real-time data and information (All)

15:00-15:30 Overview of the SWFDP-SeA (RFSC[4])

[4] RFSC :Regional Forecast Support Centre

- Geographical coverage
- Model resolutions and forecast period

15:30-16:00 Tea Break

16:00- Visit to the Department of Hydrometeorological Service of Viet Nam (All)

19:00 Welcome Dinner (*TBC*)

Day-3 (22 November 2017)

09:00-09:30 Summary of Day 2 (Chair)

09:30-10:00 FFGS Advanced functionalities (HRC)

- Multi-NWP QPF ingestion
- Landslide susceptibility mapping
- Riverine Routing
- Urban Flash Flood EWS
- Seasonal and sub-seasonal discharge prediction

10:00-10:30 Flash Flood Hydrometeorologist Training Programme (HRC)

10:30-11:00 Tea Break

11:00-11:30 Roles and responsibilities of the participating NMHSs and the Regional Centre in SeAFFGS (WMO)

11:30-12:00 Facilitated discussions on the national professional and technical capacities needed for national project operations (All)

12:00-12:30 Organizational and management aspects of project planning and implementation (WMO)

12:30 – 14:00 Lunch

14:00 -15:00 Facilitated discussion on interest of countries to participate in the project, including establishment of the Regional Centre (All)

15:00-15:30 Next steps and work plan (HRC)

15:30-16:00 Tea Break

16:00-16:30 Review and adoption of decisions and recommendations (All)

16:30-17:00 Final remarks and closing of the meeting

Day-4 (23 November 2017)

Joint Morning Session (SWFDP-SeA and SeAFFGS) (Second floor-70 seats)

Linkage between SWFDP-SeA and SeAFFGS

09:00-09:30 Linking SeAFFGS with SWFDP-SeA (WMO)

09:30-10:00 High Resolution Mesoscale NWP QPF capabilities and requirements of the SeAFFGS (RFSC-Ha Noi, HRC)

10:00-10:30 Nowcasting capabilities and potential use in SeAFFGS (RFSC-Ha Noi, HRC)

10:30-11:00 Tea Break

11:00-11:30 Towards a common user interface (HRC)

11:30-12:00 SWFDP-SeA and SeAFFGS joint training activities (HRC,WMO)

12:00-12:30 Recommendations and next steps

12:30 – 14:00 Lunch

Afternoon Session (SEA-SC Meeting) (Second floor-32 seats)

------End of Meeting------

ANNEX 3

Development and Implementation of International and Regional Flash Flood Guidance (FFG) and Early Warning Systems

Project Brief

SOUTHEAST ASIA FLASH FLOOD GUIDANCE SYSTEM (SeAFFGS)

Summary

The purpose of this project is the development and implementation of regional flash flood guidance and early warning systems. The approach will entail development of regional technology, training, protocols and procedures to address the issues of mitigating the impacts of flash floods and the application of such a system allowing the provision of critical and timely information by the National Meteorological and Hydrological Services (NMHSs) of the participating countries.

To accomplish this, the World Meteorological Organization (WMO) will cooperate with the Hydrologic Research Centre (HRC), San Diego, USA to implement a flash flood guidance and early warning system designed along the lines of similar systems that have been made operational in different parts of the world. In cooperation with a designated Regional Centre, normally located within one of the participating countries, the project will be executed by the participating national hydrometeorological services with the HRC providing technical assistance in cooperation with NOAA/National Weather Service for the system implementation and training; and WMO providing technical backstopping and supervisory services including Monitoring & Evaluation of the project. *Within the scope of Canada CREWS SEA and SIDS project, Environment and Climate Change Canada (ECCC) is providing funding support for the project.*

Specifically the countries to be included in the project are proposed to be the following:

Cambodia, Lao PDR, Thailand, and Viet Nam

Based on estimation of rainfall from satellite imagery and available gauges, the system will provide the NMHS of each participating country with an estimate of the precipitation amount and an indication (guidance), based on physically-based hydrological modelling, as whether it would generate a bankfull discharge (e.g., minor flooding) at the outlets of small, flash flood prone basins throughout each country. The NMHSs will integrate local knowledge from other sources (their national networks, observers report, etc.) to validate the guidance and issue as required a warning through channels proper to each country.

Technical assistance includes the development and implementation of the flash flood guidance and warning system as well as research and development into system enhancements, including inclusion of infrared and microwave technology for satellite rainfall estimates, as needed for the different implementations, and training and capacity building on system operations and applications to disaster risk reduction (i.e., an end-to-end system approach). The approach will provide a tool for each country within the specified region to access the data and information needed to develop alerts and warnings for flash floods.

The main objective of this project is, therefore, to contribute towards reducing the vulnerability of the region to hydrometeorological hazards, specifically flash floods, by developing and implementing a flash flood guidance system to strengthen regional and national capacity to develop timely and accurate flash flood warnings.

1. Beneficiaries

In many areas of the world, flash floods are a regular phenomenon accounting for loss of human life and significant economic and social damages, adding up to hundreds of millions of Euros for a single event. Flash floods can affect not only mountainous and hilly rural areas with sparse settlements but also major urban areas. In addition, an increase in their frequency and magnitude is anticipated as a consequence of climate change.

Implementation of a flash flood guidance system would provide benefits to all societal and economic stakeholders of each country.

A key benefit of the proposed system is that it is capable to provide early awareness of impending local flash flood threats for all potentially vulnerable communities. A true value of the system will be to provide rapid assessments of the potential of flash floods allowing improvement of the early warnings for the occurrence of a flash flood and therefore allowing for more rapid mobilization of response agencies.

The system implementation also provides capacity building and cooperation for effectively mitigating disasters from flash floods. Training and capacity building will be a strong component of the implementation of this program. There will be opportunities in cross-training of hydrologists and meteorologists from countries within the region and with different backgrounds and skills in hydrometeorology, which forms the basis of flash flood detection and prediction.

The availability of the system guidance products will also help to improve the way flash flood events on trans-boundary rivers are addressed, encouraging international technical cooperation and regional cooperation in preparing public awareness campaigns and response strategies.

Primarily aiming to improve national service delivery capabilities to deal with flash flood threats, the implementation of the flash flood guidance system will also provide the opportunity for enhancement of regional collaboration of disaster mitigation and response agencies and improvement of community awareness of flash flood disaster threat and mitigation.

Training programs will be designed to include NMHSs to develop strong scientific and technical capabilities to use the FFG system and further to include disaster management agencies where the responsible agencies will be involved in system validation programs which will require determinations of where flooding did or did not occur. The issuing of warnings based on flash flood guidance and flash flood threat products will conform to establish national practices, if existing; alternatively the project could provide support to a national dialogue for their development. The establishment of such criteria requires understanding of the hydrometeorological processes and prediction uncertainties, as well as capabilities of the population to take effective action. Such a process will encourage the national agencies to interact with local communities both in establishing such criteria, and in regular reviews of their effectiveness. The responsible agencies will need to design awareness campaigns for both municipal agencies and the public at large concerning the interpretation of flash flood warnings and effective action strategies (i.e., what to do in when flash flood warnings are received). To be effective, this effort will require input from local community representatives (emergency response agencies and the public at large). Maintaining these public awareness campaigns and information distribution as ongoing efforts required to reduce flash flood casualties will be needed.

The flash flood guidance system functions at one level as a disaster mitigation tool by mitigating loss of life and livelihoods, and by rapidly targeting disaster response agencies to potential problem areas. On another level it can be used to provide maps of flash flood probabilities, threats and decision-aiding for imminent actions. These maps can be used to provide a risk assessment tool and guidance concerning the development of infrastructure – that is, as a guide to where special care should be taken in the design and locations of particular facilities as the population expands to live in flash-flood prone areas.

All these agencies will be involved in system validation programs which will require determinations of where flooding did or did not occur. To be effective, this effort will also require input from local community representatives (emergency response agencies and the public at large).

2. Sector-Level Coordination

Through the project partners representing the technical aspects of the system implementation and operation will be brought together with agencies in disaster risk reduction to develop a detailed work plan that will enable operational engagement of technical and disaster risk reduction agencies for implementation of the system.

The work plan for disaster risk reduction will address activities such as joint training programs and public outreach and awareness programs. This effort will provide the opportunity for enhancement of regional collaboration of disaster risk management agencies and improvement of community awareness of flash flood disaster threat and mitigation. Training programs will be designed to include NMHSs and the disaster management agencies.

3. Technical Design

Flash floods are a hydrometeorological phenomenon that requires (a) integration of meteorology and hydrology in real time and (b) ingestion of local information and expertise for reliable warnings. The system design aims to allow for both. This system will serve as a catalyst to develop protocols in line with regional and country norms pertaining to other event warnings. The system allows that even within a region different countries will develop their own manner of system configuration and use adapted to local requirements as a tool for developing flash flood warnings and watches together with other local timely information.

Important technical elements of the Flash Flood Guidance and Warning System are the development and use of a bias-corrected satellite precipitation estimate field, high-resolution numerical weather prediction model outputs (where available), and physically-based hydrological modelling to determine flash flood guidance and flash flood threat. These system elements can now be applied anywhere in the world. Real-time estimates of high resolution precipitation data from satellite are now routinely available globally (and can be further enhanced with locally available radar estimates of precipitation). Global digital terrain elevation databases and geographic information systems may be used to delineate small basins and their stream network topology anywhere in the world. In addition, there are global soil and land cover spatial databases available to support the development of physically-based soil moisture accounting models (see flow chart in Figure 1). The real-time satellite precipitation estimates needed to drive the regional systems on a global scale (using global data provided by NOAA and the WMO) will be developed first followed by the development of specialized products.

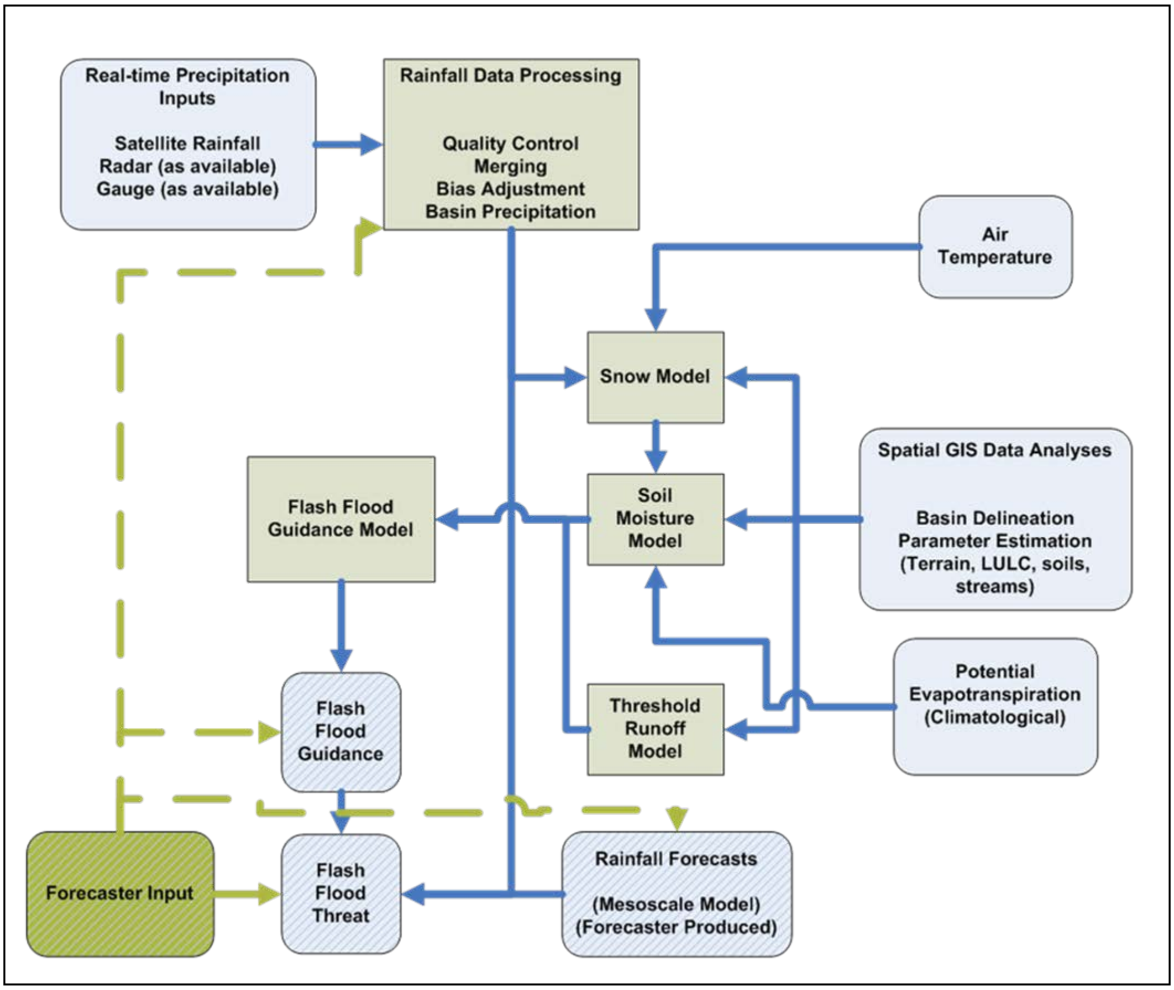

Figure 1: Schematic Flow Chart of the Flash Flood Guidance System

The system allows the NMHSs to use local nowcast/short-term-forecast methods they wish to use to issue the warnings, including (and strongly recommended) local forecaster adjustments. The system design allows this coupling with the existing or developing NMHS approaches on a national or even local scale.

System flexibility and system capability to engage local forecasters should help greatly towards the development of regional/local protocols for integration within existing warning dissemination systems.

The system will provide evaluations for the threat of flash flooding over time scales of hourly to six hours and for basins on the order of 150 sq. km. Given the computational burden and depending on available computational resources, it is very likely that the most valuable lead times for system use will be 3 - 6 hours. Efforts might also be undertaken through the application of numerical weather prediction model outputs to extend the range of threat prediction to 48 hours.

4. Implementation Approach

The system design is such that it allows for efficient global data ingest and it supports regional cooperation among NMHSs. The design is characterized by distributed operations and functions. Several centres of computation and product dissemination will support the operational functions of the NMHSs through the timely provision of data, software, hardware and training. The overall organizational structure is shown in Figure 2.

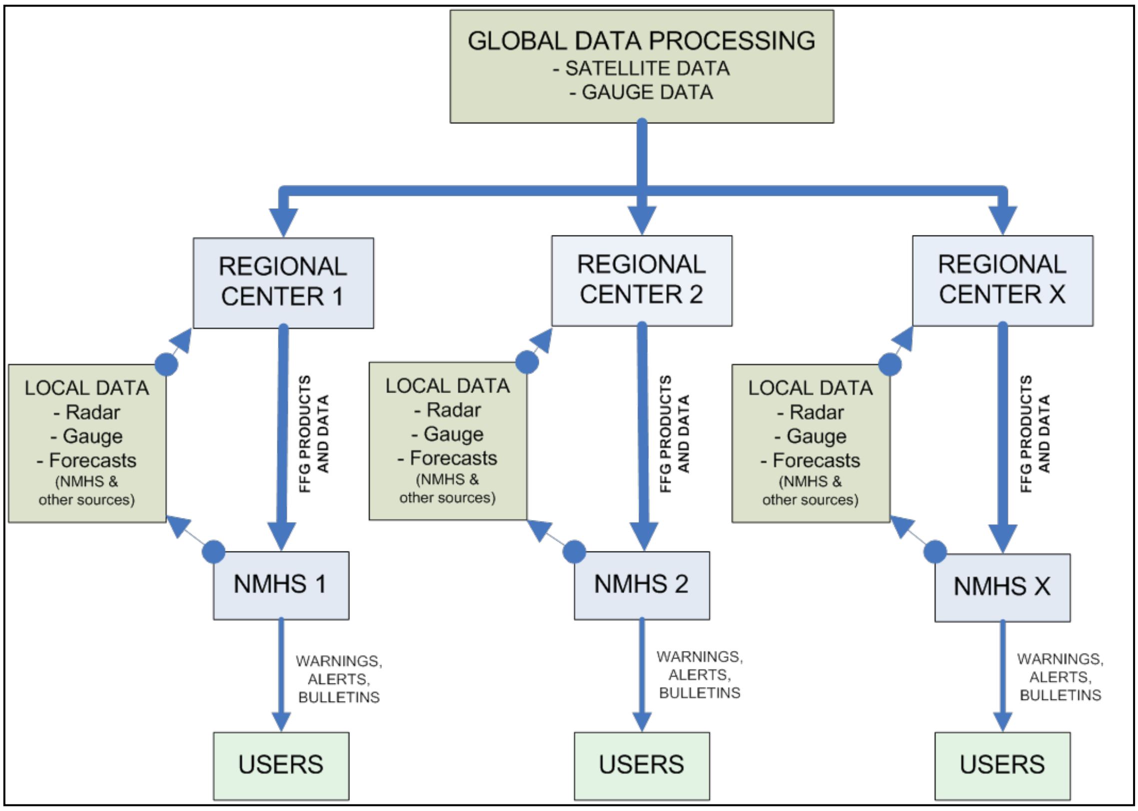

Figure 2: Flash Flood Guidance and Warning System as a distributed system of computer hardware, data and information to support NMHSs worldwide.

The interface with global information is the link to real-time global satellite precipitation estimates and global in situ observations will be through one or more of the World Meteorological Organization (WMO) Global Centres.

All requisite real-time data (global, regional, and local) are ingested at servers located at the Regional Centres where the FFG software is installed. Graphical and text products are then provided to the participating countries through a secure internet connection.

It is necessary to designate a focal institution (most probably an NMHS or an existing Regional Centre with proven scientific and technical capabilities) and with existing communications and infrastructure capabilities to support a Regional FFGS centre. Key operational Regional Centre responsibilities are:

- Disseminate real-time country graphical products from the FFGS for the NMHSs in the region;
- Collect available real-time local meteorological data for ingest to the FFGS for the development of regional products;
- Support regional flash flood operations by:
  - Provide regional validation of products and formulation of plans for improvements, and
  - Provide communications for system analyses to NMHSs of the region.

- Provide communications of regional system modifications necessary to system developers;

- Develop a historical archive of the system products;

- Support WMO and developers with regional training of NMHS representatives; and,

- Provide routine maintenance and IT support for the FFGS server.

NMHSs functions pertaining to the use of the flash flood guidance and warning system will include: country hydrometeorological analysis using the system products and information and other local products and information; country modifications of the regional-centre flash flood guidance and precipitation nowcasts on the basis of within-country most-recent data and information; development of local flash flood watches and warnings; monitoring of system performance (availability and effectiveness) and feedback to the regional centre; and links to within-country disaster management agencies for effective disaster risk reduction. Resources of country NMHSs will determine the actual configuration and type of software used in each case, given the provision of within-country baseline software and links to regional centre facilities as discussed previously.

It is expected that the products available from the Regional Centre will be adequate to support a range of processing capabilities at the NMHSs, from those that can be performed on a PC with Excel software to those that support interactive graphical generation of products. This provision will allow the NMHSs of all the countries to develop real time flash flood forecasts and watches/warnings using the global-data information and their local data and information. There will also be a provision for countries that are willing to share local real-time data to produce graphical products and updated guidance information for their areas to complement the locally produced products with the baseline configuration mentioned.

One key to sustainability is confidence in a reliable, accurate system. To accomplish this, reliability evaluations will be included in the concept of operations.

5. Transition and Exit Strategy

Upon completion of the project, each country within the region will have access to the flash flood guidance and early warning system data and products via the internet. The required data will be accessed and processed through the regional facilities. At the country level only a PC and internet connectivity will be required to access the data and products required to evaluate potential flash flood threat, making the system very sustainable. The regional centres will be selected based on resource requirements to ensure appropriate access to the required data and maintenance capacity.

Much of the effort to ensure sustainability of the flash flood guidance and early warning system will be through training and cooperative development efforts. This approach is intended to ensure ownership and full operations responsibility. In addition, a concept for the operation of the system within the existing operations protocols of the countries will be outlined for each country during training. A User Guide will be developed for the Regional Centre for system operations and maintenance.

6. Project Implementation

Project implementation is based on the basis of a Project Implementation Plan (PIP) that will be discussed during the initial regional planning meeting. The Plan will provide information with regard to essential requirements and criteria that need to be met for the successful implementation of the project. These requirements include: Availability and accessibility of critical input data and information including geo-spatial information, historical and near real-time meteorological and hydrological data, basic institutional infrastructure and technical/professional expertise of participating meteorological and hydrological services.

The PIP including a work plan will be discussed during the initial planning meeting with principal stakeholders and beneficiaries of the project.

7. Institutional status

In February 2009, WMO signed a Memorandum of Understanding (MoU) with USAID, HRC, and NOAA on the implementation of the Flash Flood Guidance System with global coverage project. In June 2012, the MoU was renewed until the end of 2017. Funding is available from USAID to support Initial Planning Meeting of the Southeast Asia FFG System.

Furthermore, A contribution agreement between Environment and Climate Change Canada (ECCC) and WMO for the project entitled ***Building Resilience to High-Impact Hydrometeorological Events through Strengthening Multi-Hazard Early Warning Systems (MHEWS) inSmall Island Developing States (SIDS) and Southeast Asia (SEA)"*** was signed on 19 February 2017. Being a major output of the project's Southeast Asia component, the development and implementation of the SeAFFGS will be funded by ECCC for the lifetime of the project (until March 2021).

As a result of the expression of interest of participating countries in the Southeastern Asia-Oceania Region in the Flash Flood Guidance System, the MoU was revised in 2015 to include support for the initial planning meeting. This meeting will allow:

- Country experts to see first-hand the technical components of the FFG system;
- Country experts to assess the potential utility of adopting such a system within their operations;
- Understanding of the requirements of national centres and the regional centre;
- Understanding of national implementation requirements including professional staff;
- Understanding of the regional and national primary data collection required for the initiation of the project; and
- Countries to consider the overall project and whether each wishes to commit to undertaking and supporting the implementation of the project in the Southeastern Asia-Oceania Region.

Should countries wish to commit to the implementation of the project, countries would then decide on their national centres and the regional centre. WMO in collaboration with financial, technical and regional partners now plans to organize the initial planning meeting where interested countries through the Permanent Representatives of WMO Members and their Hydrological Advisors or designated alternates are expected to discuss all aspects of the proposed project and eventually express whether they commit to participate and cooperate in the project activities and provide technical information that is critical for the successful implementation of the project in the region.

Aside from the commitments made by participating national agencies, it will be essential to have full details available on issues such as in-kind contributions through infrastructure and personnel, areal information specifying the area(s) to be covered by project activities in the region, availability of supporting data and information including geospatial and historical hydrometeorological information. Likewise, the governance of the project and the roles and responsibilities of national participating centres and a Regional Centre will be on the agenda of discussion with expected recommendations and decisions to be made during the meeting. This will be compiled through information received from countries and services on the basis of a Requirements Document to be developed.

The project will be phased over a period of several years that will be determined during the initial planning meeting, with the bulk of the development and implementation activities occurring during the first year to two years. The remaining years of the project will focus on training, system operations/evaluation and validation of system outputs to ensure on-going sustainability.

ANNEX 4

GLOBAL FLASH FLOOD GUIDANCE SYSTEM

Southeast Asia Flash Flood Guidance System (SeAFFGS)

IMPLEMENTATION REQUIREMENTS

Document Purpose

This document provides guidance to project participants, in particular National Meteorological and Hydrological Services (NMHSs) on minimum requirements with respect to professional capabilities, availability of data and information as well as computational and communication infrastructure to implement a **Flash Flood Guidance System (FFGS)** with global coverage. In addition, the document provides information of the functions of the Regional Center and NMHSs leading to the delivery of flash flood guidance products on regional and national levels.

These requirements reflect a system that provides timely and useful data and information based on robust communication infrastructure in a form that is consistent with the operations in place in many of the National Meteorological and Hydrological Services (NMHSs) throughout the world. Of primary importance is to establish a system that becomes part of NMHS operations and is used as the primary tool by these services for providing flash flood alerts/warnings to the appropriate agencies and/or the public.

Overview of the FFGS

The primary purpose of the FFGS is to provide real-time informational guidance products pertaining to the threat of potential small-scale flash flooding. The system is designed to address the reduction in devastation caused by flash floods in terms of reductions in the loss of life, suffering and property damage. The system provides the necessary products to support the development of warnings for flash floods from rainfall events through the use of remote sensing-based rainfall estimates (primarily satellite).

The system outputs are made available to forecasters as a diagnostic tool to analyze weather-related events that can initiate flash floods (e.g., heavy rainfall, rainfall on saturated soils) and then to make a rapid evaluation of the potential for a flash flood at a location. The system empowers users with readily accessible observed data and products and other information to produce flash flood warnings over small flash flood prone basins. The system is designed to allow the addition of experience with local conditions, incorporate other data and information (e.g., Numerical Weather Prediction output) and any last minute local observations (e.g., non-traditional gauge data), to assess the threat of a local flash flood. Generally, evaluations of the threat of flash flooding are done over hourly to six-hourly time scales for basins from 100 - 150 km^2 in size.

Important technical elements of the FFGS are the development and use of a precipitation gauge-based bias-corrected satellite precipitation estimate field and the use of hydrologic modeling. The system then provides information on rainfall and hydrologic response, the two important factors in determining the potential for a flash flood. The system is based on the concept of **Flash Flood Guidance** and **Flash Flood Threat.** Both indices provide the user with the information needed to evaluate the potential for a flash flood, including assessing the uncertainty associated with the data.

The flash flood guidance approach to developing flash flood warnings rests on the comparison in real time of observed or forecast rainfall volume of a given duration and over a given catchment to a characteristic volume of rainfall for that duration and catchment that generates bank full flow conditions at the catchment outlet. **Flash Flood Guidance** (FFG) is that characteristic rainfall volume for the given duration over the small catchment that generates bank full flow conditions at the catchment outlet. FFG is updated in time based on current soil water deficit (as determined by antecedent soil moisture conditions), rainfall, evaporation, and groundwater losses. If the observed or forecast rainfall volume exceeds the

FFG of the same duration, this excess is termed the **Flash Flood Threat** and flooding at or near the catchment outlet may be likely (Figure 1).

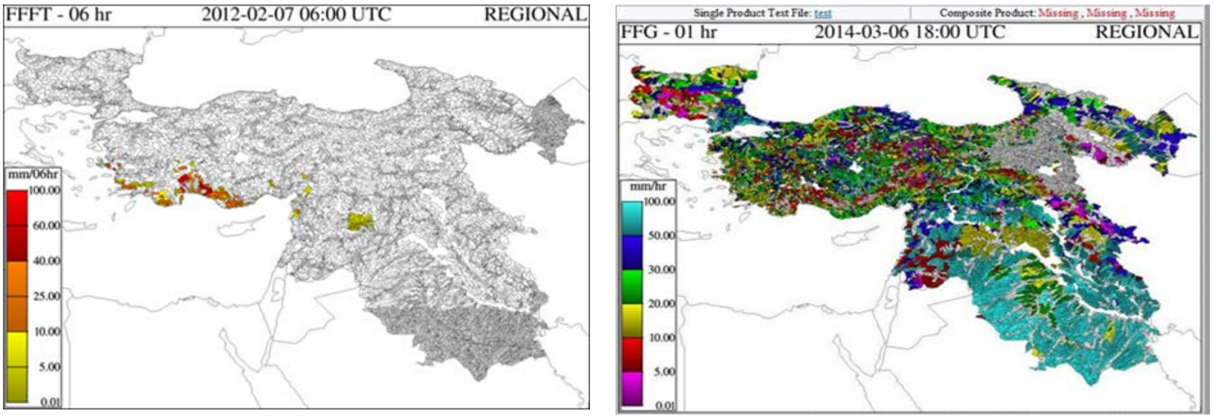

Figure 1: 6hr-Flash Flood Threat and 1-hr Flash Flood Guidance for the Black Sea and Middle East Flash Flood Guidance System

Global Flash Flood Guidance System Program Background

The purpose of the Global FFGS (GFFGS) program is the development and implementation of regional flash flood guidance and early warning systems. The approach entails development of infrastructure on a global scale to then support the development and implementation of regional flash flood guidance projects comprising of technology, training, protocols and procedures components to address the issues of mitigating the impacts of flash floods.

Regional flash flood guidance and early warning systems are designed based on programs in Central America, Southeast Asia, Black Sea Middle East and Southern Africa. The project approach is to provide a tool for each country within a specified region to access the data and information needed to develop alerts and warnings for flash floods. The main objective of this project is, therefore, to contribute towards reducing the vulnerability of people around the world to hydrometeorological hazards, specifically flash floods, by developing and implementing flash flood guidance systems to strengthen regional capacity to develop timely and accurate flash flood warnings.

The data and information part of the requirements also provides guidance with respect to the selection of areas/basins on national level that can be covered with a flash flood guidance system based on the availability of critical data and information.

Implementation of this program is in concert with the World Meteorological Organization’s Flood Forecasting initiative guided by the Hydrology and Water Resources Branch of the Climate and Water Department of WMO. In the context of this initiative, the World Meteorological Congress has endorsed the implementation of a Flood Forecasting Initiative. A goal of this initiative is to develop and implement programs that encourage hydrologists and meteorologists to work together towards the improvement of operational flood forecasting services.

The GFFGS program is being accomplished under the Memorandum of Understanding (MoU) noted below [5] through funding by the U.S. Agency for International Development/Office of U.S. Foreign Disaster Assistance (USAID/OFDA).

The system design is such that it allows for efficient global data ingest and support of regional cooperation among NMHSs. The system design is characterized by distributed operations and functions on global, regional and national levels. Centers of computation and product dissemination will support the operational functions of the NMHSs through the timely provision of data, ancillary information, software, hardware and training. A schematic of the global-regional-national system is shown in Figure 2.

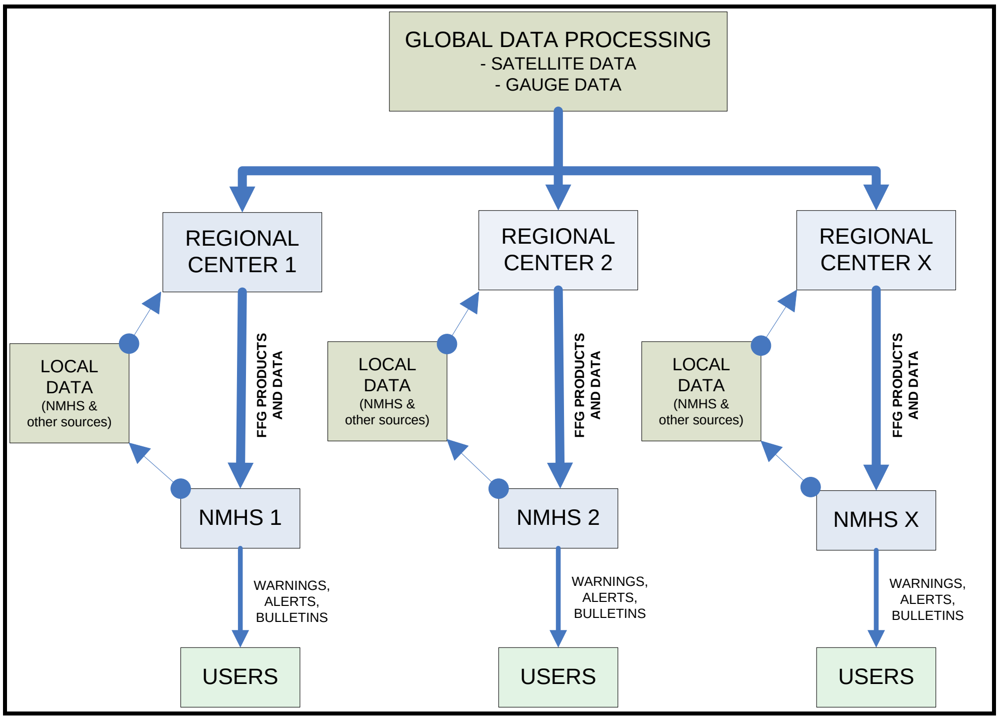

Figure 2: GFFG System Schematic – Global Implementation

Implementations of regional projects are achieved through the development of an interface with the global core and with the Regional Center. The global data core link to real-time global satellite precipitation estimates will be through the U.S. National Oceanic and Atmospheric Administration/National Environmental Satellite, Data and Information Service (NOAA/NESDIS). If required, global in situ observations will be provided through one or more of the World Meteorological Organization (WMO) Global Centers (Washington, DC; Moscow; and Melbourne) and Regional Telecommunication Hubs including Bangkok, Beijing, New Delhi and Tokyo. The primary functions of the global data ingest and processing core are to:

- Provide global data ingest and quality control;
- Access global meteorological information to supplement data collected at the regional level as needed;

[5] MoU "Establishing a Cooperative Initiative among the World Meteorological Organization, Hydrologic Research Centers, U.S. National Oceanic and Atmospheric Administration/National Weather Service and the U.S. Agency for International Development/ Office of U.S. Foreign Disaster Assistance for the Flash Flood Guidance System with Global Coverage Project"

- Maintain correspondence with the Regional Centers; and
- Implement computational system changes.

The Regional Centers will require appropriate communications and infrastructure facilities to support operations. The proposed responsibilities of the Regional Centers are outlined in Appendix A.

In summary, the Regional Centers responsibilities are:

- Disseminate real-time detailed country graphical products for the NMHSs in the region;
- Provide routine regional hydrometeorological analysis;
- Provide communications for system analyses to NMHSs of region;
- Provide communications of regional system modifications necessary to developers;
- Provide regional flash flood hazard information;
- Provide regional validation of products and formulation of plans for improvements;
- Provide daily guidance discussion to NMHSs from a regional perspective;
- Collect available real-time meteorological data for the development of regional products;
- Provide regional training of NMHSs representatives; and
- Provide, if necessary, a computational platform for country scale real-time computations and modifications of flash flood guidance products for those NMHSs that lack adequate computational capabilities.
- Provide routine maintenance and IT support.
- Develop a historical archive of the system products.

NMHS functions pertaining to the use of the flash flood guidance and warning system include:

- Develop country hydrometeorological analysis using the system products and information and other local products and information;
- Develop country adaptations of the flash flood guidance and precipitation nowcasts on the basis of within-country most-recent data and information;
- Develop local flash flood watches and warnings as required;
- Provide data and information to the Regional Centers (based on regional agreements);
- Monitor system performance (availability and effectiveness) and feedback to the Regional Centers; and,
- Communicate with user agencies for effective disaster risk reduction.

Resources of country NMHSs will determine the actual configuration and type of software used in each case, given the provision of within-country basic software and communication links to Regional Centers facilities.

It is expected that the products available from the Regional Centers will be adequate to support a range of desk top computer-based processing capabilities at the NMHSs, from using simple spreadsheet software to those computational facilities that support interactive graphical generation of products (much like the capability of the Regional Centers). This provision will allow the NMHSs of participating countries to develop near real-time flash flood guidance and warnings.

Data and Information Requirements

To ensure that the FFGS provides the highest quality data and information to forecasters, various historical and real-time hydrometeorological data and other information are required in order to develop, implement and operate the flash flood guidance systems. Historical data and information are needed for the development of the system and calibration of the models. Real-time data are needed for system operations. Terrain and other spatial-database information are used to delineate the small catchments for which flash flood guidance will be computed, to calibrate the models and to operationalize the flash flood guidance information.

It cannot be emphasized enough that quality data and information are needed to provide the optimum system for use by forecasters for the development of flash flood warnings.

Data and information needs are detailed in Appendix B. Appendix C is a survey of automatic rain gauges and weather stations. This information is important to fully understand the current status of these systems.

Resource Requirements

Personnel

The system is designed to be used operationally and jointly by meteorologists and hydrologists. The following expertise is recommended at the Regional Centers and country levels for the primary users, mainly the system operators.

Recommended Minimal Available Expertise

Area of Expertise	Regional Centers	Country NMHS
Have a meteorological or hydrologic technical background	Both meteorological and hydrologic expertise	Either meteorological or hydrologic expertise
Have experience in operational quantitative weather or hydrologic forecasting specific to the region or country	Priority	Priority
Have experience in weather-related hazard emergency management operations	Priority	Priority
Have experience in or knowledge of quantitative analysis of satellite-based rainfall estimates	Priority	Preferred
IT capability for server system administration, network connectivity, and product availability	Priority	Preferred

Both the Regional Center and the country NMHS should operate on a round-the-clock basis either continuously year-round or at the minimum during seasons with significant flash flood risk.

Computers and Communications

Servers using the LINUX operating system will be provided for the Regional Centers through the project. The country NMHS requires a current-generation PC and an internet connection with periphery devices in order to access products from the internet. The Regional Center will need hi-speed internet service and, potentially, access to GTS/WIS.

Appendix A

Regional Centers Roles and Responsibilities

Operations Overview – Regional Centers

The Regional Centers (Centers) play a critical role for the sustained operations of the Flash Flood Guidance System with global coverage (FFGS) within the region. The Centers will be the focal point for access by the countries (including their own) to data, information and products required to make rapid decisions with regards to flash flood threats. The Centers will also play a role in training (or providing guidance) and with hydrometeorological analyses within the region. The Centers will also be responsible for maintaining the server nodes of the FFGS. The Centers is essentially the organization at which all regional data and knowledge exist for the successful operation of the FFGS in the region. Accordingly, the Centers role in the FFGS process requires a higher standard of computational infrastructure and professional expertise than that of the NMHSs of participating countries within the region. As with the NMHSs, the schedule for performing their specific operations is based on specific operational requirements as well as the current or anticipated flash flood hazard.

Responsibility for global data ingest and for regional information and communications (e.g., highlighting particularly vulnerable areas within the region, regional hydrometeorological analyses), training and regional coordination of flash flood guidance and warning operations, as well as regional FFGS validation lies with the Centers. NMHSs will work with the Centers in developing flash flood guidance/warning protocols that are appropriate at national level and consistent for the region and mode of FFGS operation, as well as by their particular links to within-country users (e.g., disaster management agencies). Responsibility for flash flood guidance and warnings as well as disaster preparedness and coordination with disaster management/response agencies lies with the country.

The Regional Centers will play a key role in the development of regional protocols and operational requirements and in defining any design requirements specific for that region. To do this the Centers will need to coordinate inputs from the countries during all phases of implementation.

Regional Centers Operational Roles and Responsibilities

The Centers will maintain and operate the Regional Linux server which computes and disseminates regional and country FFGS products (data and products). In meeting its responsibility to maintain the base node of the FFGS system, the Centers will have the following roles, responsibilities, and operations to the extent possible:

- As needed, the Centers will develop and maintain a local database of contributed, real-time input products from participating NMHS agencies and make available those products to the automated acquisition processes of the FFGS Computational Server. This will require that the Centers work with the countries to develop a set format of the data to be transferred to the Centers for use developing this real-time database that feeds the FFGS.

- Centers forecasters will work directly with the country forecasters in evaluating and applying the FFGS products and will provide critical hydrometeorological expertise where required.

- Where appropriate, the Centers will be available for the briefings and discussions needed to properly evaluate flash flood potential using the FFGS tool. The Centers forecasters will work with the country forecasters to ensure that they understand the weather forecasts and to provide consistency, including evaluating and interpreting the applicability of current and forecast precipitation events.

- The Centers will evaluate the FFGS products from a regional perspective and will communicate this perspective to the countries as appropriate. The Centers will ensure consistency of FFGS products throughout the region.

- The Centers will provide regional and national validation of system results and will advise the countries of the presence of noted biases in system outputs.

- Where appropriate, the Centers will coordinate the issuance of consistent flash flood watches and warnings (as applicable) using the FFGS tool as well as other information and tools available.

- The Centers will provide routine training/workshops on system operations, product interpretation and development, product verification, etc. to country forecasters.

- The Centers will coordinate with the global data processing Centers in matters of data flow and communications or for conveying information regarding potential improvements that will affect the region products.

Centers System Management/Maintenance Roles and Responsibilities

Even though the FFGS servers are designed to be fully automated, there will always remain a critical need for ongoing observation and quality control of its processing tasks and data products. This requires expertise from two basic categories: systems administration and operational quality control of the data products. Skills in both areas of expertise are needed to properly monitor and confirm the overall performance of the system. This can be fully achieved only through the cooperative efforts of both IT Staff and Forecasters. In fulfilling its system maintenance responsibilities, the Centers need to perform the following activities.

- Maintain Network Connectivity and Data Availability – This relates primarily to the systems administration efforts of IT staff. Of concern are potential problems related to internet and/or GTS service availability, network cabling, switches, or any one of numerous hardware and security issues related to the servers themselves. The assessment and correction of potential problems relating to any of these areas requires specific technical skill and an understanding of the systems and technologies involved.

- Product Quality Control – This relates to the function of the forecasters at the Centers. Their expertise in hydrology and meteorology is required to properly understand the relative quality of the FFGS input and output products at any given time. Accordingly, Centers forecasters must perform quality control procedures on the data and outputs and determine whether or not any perceived problems are the result of a parametric shortcoming, a failure in one of the FFGS models, or if it might relate to the quality or availability of the real-time input data that drives the system.

- Operational Process Monitoring – In order to successfully fulfill the specific responsibilities of IT staff and forecasters identified above, both groups must engage in a necessarily cooperative effort of routine and systematic review of system processing activity. This involves regular inspection of system image products, data products, status indicators and log files as a means to confirm the proper operation and health of the system while maintaining a keen familiarity with the status quo in order to immediately recognize any deviation from it.

Training Responsibilities

The Centers will be directly involved in the various training programs during implementation and operations. Training programs can involve both Centers staff and country staff. Regional representatives will be equipped to play a fundamental part in the training of country staff, especially during system operations. The primary purpose of training is for Centers representatives to familiarize themselves and develop a level of competency in the FFGS system basics (physical principle, components, operation, and validations), product interpretation and use, and collaboration for prediction and warning. Particular emphasis for the Centers will be placed on validation, operations, trouble shooting and maintenance, data management, communications, realistic scenarios, and preparedness for unusual circumstances or errors. Usual training programs involving Centers (and country) personnel are noted below.

Regional Workshops

An initial and final (operations) workshops are held in the region to introduce hydrologists and meteorologists to a variety of topics including the hydrometeorology of flash floods, basic system design including products, overview of the required data and information needed for system development and operations, system validation, and concept of system operations.

The operations workshop will be held after system implementation and other training programs have been completed. This workshop will be conducted at the Centers and will provide additional training for NMHS representatives from all countries within each region. The system overview and hands-on demonstrations will include presentations by the trained Centers representatives. The focus of this workshop is too identify and plan for country specific flash flood scenarios using the FFGS in addition to synthesizing coordination protocols for operations and communications between the Centers and NMHS staff. An interactive component during the operations workshop allows for a demonstration of the system. Collaboration will involve an accounting of regional and national considerations depending on geography, climate, and communications or other hardware/structural capability.

Hydrometeorologist Training Program

The main focus of this training program is to familiarize meteorologists and hydrologists with the complex interrelationships between atmospheric moisture, low level features, and geomorphology that can result in storm-specific enhancement of precipitation efficiency and increase a given precipitation event's chances to produce a flash flood. The on-line Hydrometeorologist courses for meteorologists and hydrologists focus specifically on supporting the Flash Flood Guidance systems by providing the necessary tools to assist in the forecast of flash floods. This training is available online to all FFG users (Figure 1).

On-line Interactive Training Program (Simulator)

This program provides virtual simulations of the FFGS software functions in interactive and demonstration modes. A collection of flash flood case studies from around the globe will be developed using FFGS software and archives from implemented flash flood guidance systems. Learners will be required to forecast flash flood events using the available information. Centers staff will work together with country staff to accomplish the simulator training.

Hands-on Training

This training will be conducted when the FFGS computational and communications components are in place and operational. Centers and country representatives from the region will receive hands on training simulating daily operations and developing validation programs for each region through close contact with their colleagues in the NMHSs in their region. It is expected that this type of training, perhaps more than any other, will develop a core of professional Hydrometeorologists with flash flood forecasting specialization that will be key for the sustainability and increase effectiveness of the FFGS system both regionally and within each country. In addition these professional Hydrometeorologists will utilize their hands-on experience to train regional and in-country forecasters. This will further increase the sustainability and effectiveness of the FFGS systems into the future.

Regional Training – Installation

Training will be scheduled during system installation for Centers representatives and prepare them to guide NHMS representatives in operational use of the FFGS system. This training will include the assurance for ingesting required real time inputs (e.g., radar, gauge and satellite rainfall estimates), testing system performance during operation, data archival and restoring functions, and communication components. This training will be accomplished in system administration training program during system installation and implementation at the Centers.

Ongoing Training

An ongoing regional training program involving the Centers will be developed to maintain proficiency with system operations, ensure continued system validation, and ensure continued system use and ownership. This will involve continual engagement with the community of users. Tools will be developed to build capacity to improve the system and handle more complex contingency scenarios (e.g. key data missing, failure in “normal” operations, communications, or other such events).

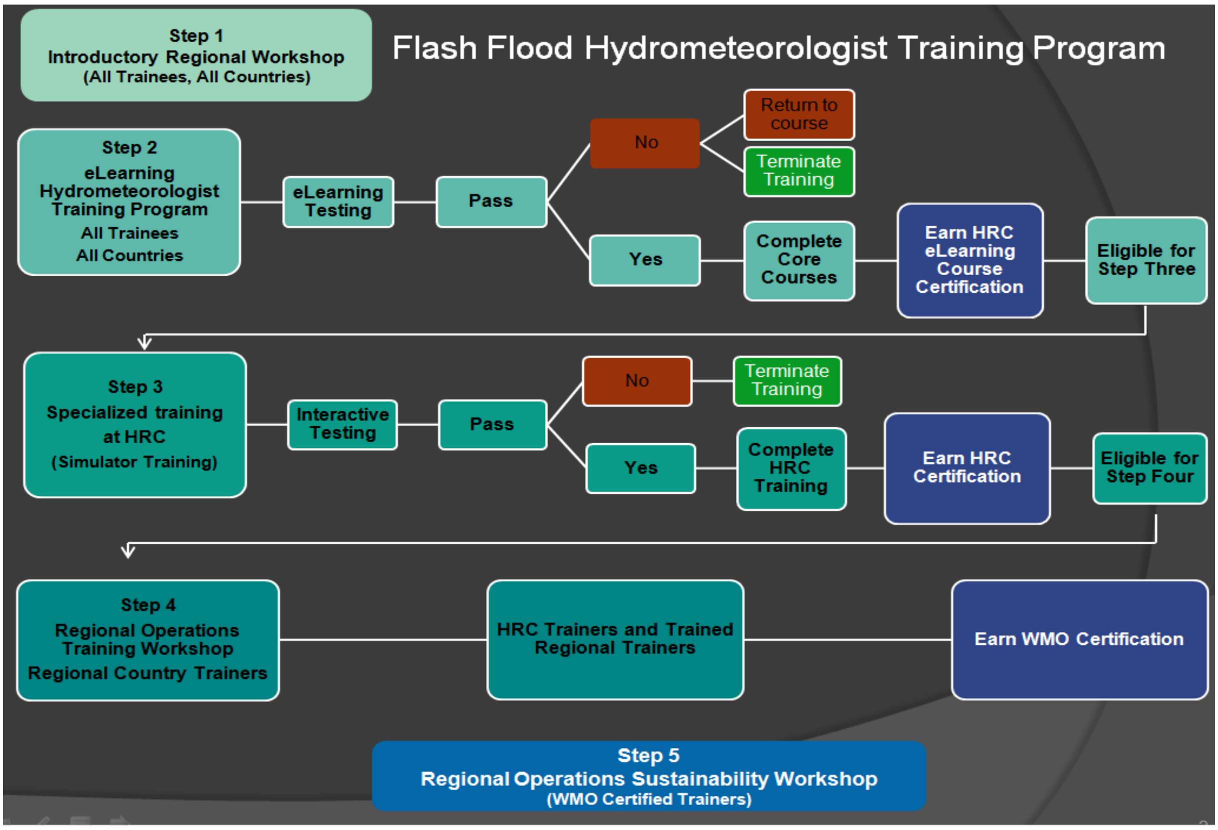

Figure-1: Flash Flood Guidance System Hydrometeorologist Training Programme

Appendix B

Data and Information Requirements

For each area or basins where flash flood guidance will be provided, various historical, real-time and state variable data and information are needed for the development and operation of the flash flood guidance system. As much of the following data and information as possible should be collected and/or made available from each country within the region. Note that the following items represent the optimum data and information requirements; system development and operations designs will consider which data are available for use.

A. Country Infrastructure Information

- Institutional capacities, responsibilities and needs for the following:
  - Rainfall monitoring and data processing
  - River and flash flood forecasting
  - Flash-flood warnings and warning dissemination

B. Spatial GIS Data, Maps

- Digital terrain elevation data (quality controlled)
- Stream network
- Lakes/reservoirs/wetlands
- Soils Data: Soil texture classification and soil depth
- Land Cover/Use
- Monthly climatological maps of precipitation, temperature and potential evapotranspiration.

C. Historical Data

- Channel Cross-Sectional Information for natural channels with drainage areas less than 2,000 km^2
- Recent hydrometeorological data, 5-20 years in record length, in <u>digital</u> format:
  - Precipitation data (hourly, daily, monthly), including the past 5 years (or as available) specifically from the current real-time rain gauges.
  - Air temperature data (hourly, daily, monthly)
  - Pan evaporation data (daily, monthly)
  - Soil moisture data for top 1 meter of soil (daily, weekly, monthly)
  - Streamflow discharge data for local streams with drainage areas less than 2000 km^2 (hourly, daily, monthly)
  - If streamflow discharge data are unavailable, stream stage data (hourly, daily, monthly) <u>and</u> associated stage-discharge curves (rating curves), also for local streams
  - Snow data such as snow depth, snow water equivalent and snowfall (hourly, daily monthly).
  - Flood frequency analysis (regional and local)
  - Flash flood occurrences (regional and local

- Stream geometry studies for small streams
- Climatological precipitation and flood studies
- Karst flow measurement studies

If recent historical data is unavailable, please provide hydrometeorological climatology data for station observations: Monthly climatologies for station precipitation, air temperature, pan evaporation, soil moisture, streamflow, radiation, wind and humidity.

D. Real-Time Input Data

FFG system uses real-time meteorological observations in WMO synop format that are disseminated through WMO GTS, including the following parameters, among others:

- Precipitation;
- Surface temperature, humidity, wind speed/direction, pressure, solar radiation;
- Snow depth and SWE; and
- Soil moisture.

Besides the SYNOPTIC reports, if additional hydrometeorological observations are available, that would be transferred to the regional centre through ftp services, may improve the system performances

Appendix C

Data Priorities

A. Real-Time Data

Real-time data is considered the highest priority for the operational FFG System.

Priority	Data Type	Time Resolution
1	Meta data for all gauges+	
1	Precipitation*	Hourly or 6-hourly preferred -OR- 3-hourly or daily
1	Surface temperature*	Hourly or 6-hourly preferred
2	Snow depth / snow water equivalent	6-hourly or daily
3	Stream flow	6-hourly or daily
4	Soil moisture measurements	6-hourly or daily
5	Humidity, wind, solar radiation	6-hourly or daily

+ Meta data includes station name &/or identifier, coordinates in LAT/LON, and elevation
** Precipitation, temperature, and snow observations may be used directly by system. Soil moisture, stream flow and other meteorological observations (frequent less available) are provided as information through system interface and may be used by forecaster to evaluate certain system output products.*

B. Historical Data

Historical data is necessary for model development and evaluation of FFG System components. The items listed below in Section 1 are higher priority, and considered equal level of priority as the corresponding priority levels of real-time data. Additional information requested in Section 2 and 3 may be during development as such data is available. The priority assignments are grouped together for Sections 2 and 3, and follow the priority level of Section 1.

For Analysis Period Overlapping Satellite Estimates

Precipitation analysis

Priority	Data Type	Time Resolution	Period of Record
1	Gauge Precipitation*	Hourly preferred -OR- 3- or 6- hourly -OR- Daily	2012 – current
1	Meta data for all gauges+		

** Gauges with good spatial coverage and relatively uniform density across country. Quality controlled data is required. Typically, most information is available from daily reporting stations.*

+ Meta data includes station name &/or identifier, coordinates in LAT/LON, and elevation.

Hydrologic Model Calibration

Priority	Data Type	Time Resolution	Period of Record
1	Meta data for all gauges		
2	Surface air temperature	Hourly or Daily preferred -OR- 3- or 6- hourly	2012 – current
3	Stream flow data++	Hourly or Daily	2012 – current
4	Pan evaporation / evapotranspiration	Daily preferred -OR- weekly or monthly	2012 – current
4	Snow depth, snow water equivalent (SWE)	Daily preferred -OR- weekly or monthly	2012 – current
4	Measured soil moisture	Daily preferred -OR- weekly or monthly	2012 – current
5	Radiation, wind & humidity	Hourly or Daily	2012 – current

++ if stream flow data is unavailable, stream stage (height) data plus rating curve may be used.

Hydrologic Model Calibration – Spatial Data

Priority	Data Type	Resolution	Period of Record
1	Soil type, soil texture, soil depth		
1	Land cover/vegetation cover/ Land use		
2	Stream survey reports / channel geometry information	For small streams, draining < 2000 km^2	Surveys within recent 10-15 years
3	Return period flow estimates&	For small streams, draining < 2000 km^2	
4	Spatial coverage of karst regions		

& if return period flows are unavailable, stream flow data for 10-20 years may be used to derive these estimates.

Additional Historical Data- Not Overlapping Satellite Estimates but Recent Time Period Preferred*

Priority	Data Type	Time Resolution	Period of Record
1	Precipitation	Hourly or Daily	5-20 years
1	Surface air temperature	Hourly or Daily	5-20 years
1	Stream flow data++	Hourly or Daily	5-20 years

2	Pan evaporation / evapotranspiration	Hourly or Daily preferred -OR- weekly or monthly	5-20 years
3	Snow depth, snow water equivalent (SWE)	Daily preferred -OR- weekly or monthly	5-20 years
3	Measured soil moisture	Daily preferred -OR- weekly or monthly	5-20 years
5	Radiation, wind & humidity	Hourly or Daily preferred -OR- weekly or monthly	5-20 years

** spatial and period of record correspondence between meteorological (P,T,Evap,SWE) and hydrological (Q, soil moisture) observations is desired for hydrologic model calibration. If corresponding time series are unavailable, data is used to evaluate climatological response.*
++ if stream flow data is unavailable, stream stage (height) data plus rating curve may be used.
[&] if return period flows are unavailable, streamflow data for 10-20 years may be used to derive these estimates.

Additional Historical Studies

Priority	Data Type	Resolution	Period of Record
4	Location of reservoirs		
4	GIS layers of watershed boundaries or stream network[%]		
5	Historical flash flood occurrences or reports		
6	Flood frequency studies		
6	Karst flow measurements or studies		

[%] digital GIS layers based on digitization of topographic map preferred and used to evaluate automated watershed delineation results.

Appendix D

NMHS Observation Network Metadata Requirements

The following metadata for the rain gauges, weather stations, and stream gauges are to be provided:

- Geographical locations (latitude and longitude in decimal degrees);
- Elevation in meters;
- Type of stations and WMO station numbers(synoptic, climate);
- Current operational status (Automatic, Manuel);
- Observation interval (hourly, 3-hourly, 6-hourly etc.,);
- Available sensors (Precipitation, Temperature, Humidity, Soil Moisture, Dew Point, Snow, SWE etc.);
- Total number of stations and number of synoptic stations that reports to GTS;
- Data transmission type (HF/VHF radio, wide area network, GPRS, satellite etc.);
- Data quality control applied (y or n); and
- Existing database (Oracle, Informix etc.).

ANNEX 5

Project Steering Committee (PSC)

The Project Steering Committee (PSC) provides overall governance of the project and its related activities throughout the duration of the project. Its membership and the Terms of Reference would be confirmed and amended as deemed necessary during the first constituting session of the PSC.

1. Standing Core Members of the PSC

Organization	Number of Representatives
Representative of the Regional Centre	1
Focal Points of NMHSs	4
Representative from Technical Development Partner (HRC)	1
Representative from WMO	1
Representative from Donor	1
USAID	1
MRC	1

Additional experts/representatives are to be invited on needs-based ad-hoc basis and observers to be invited on request.

2. Terms of Reference

The (intermediate) principle Terms of Reference of the PSC are:

- Ensure smooth implementation of project activities and achievement of the project purpose and its expected outcomes based on regul ar summary reports from National Centers and the Regional Centers;
- Provide technical and administrative guidance to the implementation of the project
- Establish an adequate Monitoring and Evaluation (M&E) system for the project and implement findings from the M&E process;
- Review and update the Project Implementation Plan (PIP);
- Promote benefits of the project on national and regional levels;
- Facilitate links with other regional and national relevant projects;
- Ensure cross-sector linkages with relevant national and international organizations; and
- Seek additional expertise and financial support to supplement project activities.

3. Communication

Meetings of the Project Steering Committee will be initially organized annually. In addition, teleconferences may be organized on a tri-semester basis or as needed to monitor project progress and solve upcoming issues. Other communication means of the PSC will include a dedicated e-mail list-server and/or a web-based E-Forum. Operational communication will be established between the Regional Centers and country focal partners (NMHSs), the Technical Development Partner (HRC) and WMO.

. Guiding Principles for the SeAFFGS implementation

The guiding principles listed below provide an overall framework for the implementation of the SeAFFGS and may be specified in more detail by the first session of the Project Steering Committee (PSC).

- Data providers remain owners of data. Data provided to the Technical Development Partner (Hydrologic Research Centre, HRC), will be used solely for the purpose of developing the SeAFFG system and such data will not be re-distributed. Data provided by National Centres to the Regional Centre will be used solely for the provision of SeAFFG products to National Centres and data themselves will not be re-distributed.

- Equal, non-hierarchical access to data and information generated by the project for project partners are in accordance with WMO Resolutions 25 (Cg-XIII) and 40 (Cg-XII) (https://www.wmo.int/pages/about/Resolution40_en.html and https://www.wmo.int/pages/about/Resolution25_en.html).

- Services provided by the Technical Development Partner and the Regional Centres are of an Advisory Nature.

- Full responsibility for national provision of flash flood warnings remains solely with the mandated organization(s) in each participating country.

ANNEX 6

LETTER OF COMMITTMENT
(SAMPLE – DRAFT)

Addressed to the Secretary-General of WMO

Subject : **Letter of Commitment regarding the Southeast Asia Flash Flood Guidance (SeAFFG) project**

Dear Mr Taalas,

Reference is made to the Initial Planning Meeting on the SEAFFG project in Ha Noi, Viet Nam from 20 to 23 November 2017, which was organized by World Meteorological Organization (WMO) in cooperation with Hydrologic Research Centers (HRC) and co-organized and hosted by the National Hydro-meteorological Service of Viet Nam with funding from USAID.

I am pleased to learn about the successful outcomes of this workshop and its conclusions which constitute a milestone in the implementation of this important project.

In this regard, I would like to confirm the commitment of (country) participation in all project activities aiming towards the achievement of the project objectives to the benefit of (country) and the Southeast Asia region as a whole.

I would also like to inform you that (name) has been designated as the focal point and (name) as alternate in all project related activities. The designated officer and his/her alternate will represent (name of the country) on the Project Steering Committee. Their coordinates are given below.

Focal Point:

Name:
Function/Role:
Address:
Phone:
E-mail:

Alternate:

Name:
Function/Role:
Address:
Phone:
E-mail:

It is my pleasure to inform you that we have designated (institution) to act as National Centre that will be responsible for the implementation of the project at the national level.

I would like to express our appreciation for the efforts so far undertaken by WMO, NOAA, HRC and the generous support of Environment and Climate Change Canada (ECCC) as donor.

Let me assure you of our full support and cooperation with the WMO Secretariat and the project partners in the successful implementation of this project.

Yours sincerely,

Name of PR

ANNEX 7

Milestones for the SeAFFGS Tentative Implementation Plan

Tentative SeAFFGS Implementation Plan

Activities for Standard FFGS implementation	2017	2018				2019												2020				
	Nov	April	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug	September	October	November	December	Jan.	Feb.	March	April	May
Initial Planning Meeting																						
Letters of commitment and points of contacts provided																						
Server Purchase																						
Obtain static and historical data																						
Obtain real-time data information - data availability/access																						
SCM1																						
National/Regional Centres complete online courses - Step 2 training																						
Complete system development																						
Development of Map Server																						
Multiple NWP ingestion																						
Regional Centre develop and provide real-time data format rqmt																						
Regional Centre operational (to collect real-time data)																						
Complete operational training at HRC - Step 3 training																						
Onsite system installation at Regional Centre																						
Follow up regional workshop - Step 4 training																						
Regional Sustainability training -Step 5 training																						
Inclusion of RADAR Data																						
INITIAL COLLABORATION VISITS																						
QC AND RADAR DATA CALIBRATION																						
RADAR DATA INGEST																						
3-WEEK TRAINING AT HRC																						
REGIONAL WORKSHOP (RADAR HYDROLOGY AND QA/QC), 2 WEEKS																						