STRATEGY AND ACTION PLAN

FOR THE ENHANCEMENT OF COOPERATION BETWEEN NATIONAL METEOROLOGICAL AND HYDROLOGICAL SERVICES

FOR IMPROVED FLOOD FORECASTING

December 2006

WMO FLOOD FORECASTING INITIATIVE –ACTION PLAN

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PART A - FINDINGS AND RECOMMENDATIONS OF THE REGIONAL WORKSHOPS HELD UNDER THE WMO FLOOD FORECASTING INITIATIVE

1. Introduction – Setting the Scene

1. Floods are one of the most devastating of natural disasters, striking numerous regions in the world each year. During the last decades the trend in flood damages has been growing rapidly. This is a consequence of a combination of increasing frequency of heavy rain (in some areas), changes in upstream land-use and continuously increasing concentration of population and assets in flood prone areas. In general, less developed countries are the most vulnerable to floods, causing considerable loss of life and damages that significantly affect the national GDP. At country and community levels important initiatives have and are being devoted to implement appropriate countermeasures, both structural and non-structural, aiming to alleviate the persistent threats of water-related disasters. Flood forecasting provides a valuable tool in reducing vulnerabilities and flood risk, and forms an important component in the strategy of "living with floods", thereby contributing to national sustainable development.

2. Preparedness and response actions of the various national disaster management authorities are highly dependent on the availability of accurate and timely meteorological and hydrological forecasting products and their appropriate and timely dissemination to authorities responsible for civil protection, and the general public. However, at present many National Meteorological Services (NMSs) and National Hydrological Services (NHSs) do not have adequate means of providing, or the knowledge to provide, extended forecasting services in flood critical situations and to communicate effectively with disaster management authorities. Longer lead-times and improved accuracy of flood forecasts require an effective use of the latest technology available in the fields of hydrology and meteorology. In many cases there is a strong need for an integration of forecasting services. Such an approach requires improved cooperation between NMSs and NHSs.

3. Recognizing the need to improve the capacity of NMSs in detecting flood-critical situations and to improve the capacity of NHSs in using meteorological forecasting information to provide accurate and timely flood forecasting services, the WMO Flood Forecasting Initiative (see ***Box 1*** below) was launched based on the outcomes of an expert meeting[1] held in April 2003.

4. The initiative started with an assessment of the state of hydrological forecasting services, and of applied knowledge in the field of flood forecasting. A series of *regional workshops were o*rganized worldwide and hydrologists and meteorologists engaged in the flood forecasting services in their countries were invited to participate. These events were followed by a *Synthesis Conference* organized by WMO from 20 to 23 November 2006; with the aim to analyse the gaps as identified during the regional workshops and to establish and agree on a framework and action plan to improve national and regional capacities for flood forecasting.

5. Flooding, due to flash and riverine floods, coastal floods, snowmelt floods, ice jams glacier lake outburst floods, landslides and mud flows, are considered in this action plan. Many NMHSs lack the means and expertise to provide fully effective flood forecasting services. Many of the challenges facing NMHSs not only influence the flood forecasting services of the countries but also other areas such as water resources assessment, addressing the impacts of climate

[1] Preparatory Expert Meeting on *Improved Meteorological and Hydrological Forecasting for Flood Situations*, Geneva, Switzerland, 1 - 2 April 2003

variability and change and the appreciation of the economic value of the services provided by NHSs. These issues are being addressed by the HWR Programme in collaboration with other WMO programmes through various others activities. This proposed Strategic Action Plan therefore strategically concentrates on the areas of collaboration between the NMSs and NHSs.

***Box 1* – The WMO Flood Forecasting Initiative**

Objectives

Improve the capacity of meteorological and hydrological services to jointly deliver timely and more accurate products and services required in flood forecasting and warning and in collaborating with disaster managers, active in flood emergency preparedness and response.

Expected results

a) Improved quantitative and qualitative weather forecasting products are available in such a way that these can be directly used for flood forecasting;

b) Medium-range weather forecasting and climate prediction tools can be applied to extend warning times and produce pre-warning information;

c) NMHSs have improved their capacity to cooperate to jointly deliver timely and accurate flood forecasting information;

d) Integrated weather, climate and hydrological forecasting information are available in a relevant format for use by civil organizations responsible for disaster preparedness and mitigation.

6. The aim of the regional events was to bring national experts from NMSs and NHSs together to discuss problems, identify major gaps that should be addressed and suggest solutions for issues related to strengthening flood forecasting capabilities in their countries. The focus is on improvement of tools and methodologies for weather and flood forecasting, including the potential benefit of seasonal climate prediction. Thus, outputs from the meetings have been the identification of opportunities and challenges in the development and use of forecasting tools available today; the use of meteorological and climatological forecasting methods including now-casting for flood forecasting; and the definition of an outreach process with a view to strengthening regional cooperation.

7. Between November 2003 and September 2006 six regional workshops on "*Improved Meteorological and Hydrological Forecasting for Floods*" were held for countries of West, Central and South Africa (RA I), Latin America (RAs III and IV), Asia (RA II), Europe (RA VI) and for the Mediterranean basin countries of RAs I and VI. These events were attended by representatives of NMSs and NHSs responsible for meteorological and hydrological forecasting in about 85 countries and a number of regional and river basin organizations, as well as of universities and research institutions. The conclusions and recommendations of all these regional workshops constituted the basic input to the global *Synthesis Conference* mentioned in ***para 4*** above.

2. Status of National Forecasting and Warning Services - Regional and Global Overview

8. During each of the regional workshops representatives of NMSs and NHSs presented reports on the status and perspectives of flood forecasting activities in their countries. In addition, technical papers on relevant flood forecasting and warning issues were also presented. The

results of the workshops' discussions, with the main conclusions and recommendations, are contained in the final report of each event. The latter, together with the country papers, thus allowed the compilation of a regional and global overview of the status of flood forecasting related issues. A ***regional overview*** is summarized in the paragraphs below.

9. In the participating ***Southern African*** (SADC) countries[2] of RA I, in general there are well established meteorological institutions and offices; meteorological data collection systems exist and there is a good collaboration between NMSs and NHSs. In some countries state-of-the-art observation tools are available (e.g. radars and satellites). Furthermore, there are regional (SADC) and sectoral organizations (e.g. SADC Water Sector, Drought Monitoring Centre, etc) in support of countries' national activities. However, there is an absence of operational flood forecasting systems in many countries, due to inadequate data transmission networks/means and relatively low utilization of potential forecast products [e.g. lack of Quantitative Precipitation Forecasts (QPF)] and, finally, a shortage of qualified personnel. One country has received international technical assistance to strengthen national capabilities after devastating floods in 2001 and 2002. The ongoing WMO SADC-HYCOS project also has the potential to support flood forecasting activities of the participating countries through provision of accurate data.

10. As regards the ***West and Central Africa*** countries of RA I, in the majority of the reporting countries[3] flood forecasting activities are very limited, mainly because of shortage of real-time data (due to inadequate or insufficient state-of-the-art observing equipment and communication networks - the continuous degradation of the observing network being one of the key issues), lack of computing equipment, outdated or lack of flood forecasting models, poor integration of meteorological inputs into hydrological models, insufficient manpower and skills among the NMHSs' staff at all organizational levels and inadequate financial resources. These are the main factors hampering the capability of many of the NMHS of the region to issue flood forecasts. However the AGRHYMET Centre is supporting the CILSS Members and other countries in the region in their hydrological monitoring activities on the major rivers and since 1998 has issued a seasonal hydrological forecasting bulletin. Furthermore, under the aegis of the HYDRONIGER and Niger-HYCOS projects, the Niger Basin Authority (NBA) also prepares, for the nine basin countries, monthly and seasonal hydrological forecasts.

11. In the ***Asian Region*** countries (RA II) there is a wide range of cooperative arrangements both between the participating countries[4], but also at the national level between hydrological and meteorological services. On the one hand there are cases where flood forecasting is done with no or minimum meteorological information, especially when either the NMS is not providing adequate forecasting products or when the NHS is at a low development stage that makes it impractical to use meteorological forecasting information, or there is minimal demand or requirement for meteorological information. On the other hand, in cases where the NHS is highly developed, it operates its own networks and sometimes receives meteorological information for use in flood forecasting. There is no wide use of Numerical Weather Prediction (NWP) for flood forecasting purposes and the use of ensemble prediction procedures, where presently used, is still mostly at an experimental level, but with the objective of using these techniques operationally as soon as proven to be reliable. The differing development status of NHSs is also reflected in the actual use of meteorological information as input to flood forecasting models; for

[2] WMO Workshop on Improved Meteorological and Hydrological Forecasting for Floods In Southern Africa (RA I), Pretoria, Republic of South Africa, November 2003

[3] WMO Regional Expert Meeting on Improved Meteorological and Hydrological Forecasting in West and Central Africa (RA I), Niamey, Niger, April 2006

[4] WMO Regional Expert Meeting on Improved Meteorological and Hydrological Forecasting in Asia (RA II), Bangkok, Thailand, December 2005

example in some hydrological services only empirical gauge correlation equations are used without making use of available meteorological information.

12. Major flood related problems affect many of the Latin American countries[5] in ***North, Central*** and ***South America*** (RAs III and IV). Flood forecasting systems have therefore been established in many of the countries, primarily for the major river basins; some of these were implemented in response to natural disasters (e.g. Central American countries, through technical assistance, were able to strengthen national capabilities after hurricane Mitch in 1998). The systems generally make use of a variety of observing systems (automatic stations, radar, satellite telemetry and imagery) and modelling techniques (stage-height correlations, flood-wave routing to modelling techniques). Many countries rely on rainfall measurement and forecasting to provide flood warning services. A Hydrological Information and Warning System is in operation for the five countries of the Rio de la Plata Basin. However, generally speaking, there is still a need to strengthen a number of the flood forecasting and warning systems. In some cases institutional arrangements pose an obstacle for co-operation between the NMS and NHS. Even in those countries where this co-operation has been found desirable, there are technical problems in view of the different spatial and temporal working scales, operational customs and practices and academic background of the professionals in the Services.

13. Flooding issues and how they are addressed[6] within the ***South-West Pacific Region*** countries (RA V) vary considerably from country to country. For example, on the smaller Pacific Island countries flooding is usually very sudden and short lived and communities tend to accept it as a natural occurrence. Often flooding occurs in the aftermath of tropical cyclone activity and thus the cyclone warning services assist in alerting communities to potential flood problems. For the larger islands, the flooding problem is of greater concern, especially in urban areas. In some countries flooding is a significant component of annual natural disaster damage and some flood warning systems have been installed. These are in various states of operation (some in disrepair) and make use of a wide range of communication (telephone to satellite telemetry) and modelling techniques. Many countries rely on rainfall measurement and forecasting to provide flood warning services and have limited real-time reporting flow measurement equipment. The interactions between oceans and flood levels (e.g. storm surges) are of importance in this region.

14. As in many other parts of the world, in many countries of ***Europe*** (RA VI) floods and flash floods cause significant damage. This has therefore generated a great need for receiving accurate and timely flood forecasts by the national flood management bodies, both for the national as well as for the large international flood-prone rivers. Although all of the reporting countries[7] have flood forecasting and warning systems, significant differences in the level of performance and outputs exist. There are a number of countries with well established flood forecasting and warning systems with high quality products and opportunities for further improvement through the use of new technologies. These systems normally combine products and information from both meteorological and hydrological services. Different tools and methods, such as NWP, QPF, remote sensing, satellite images from EUMETSAT, and hydrological and statistical models, are used to produce the flood forecasts and warnings. There are also a number of countries in which the basic infrastructure is in place, but that still require upgrading data management procedures and improved methodologies and models for flood forecasting. In some instances, there is little experience in operational practice of the application of advanced hydrological simulation and forecasting models. Finally, there are some countries which need

[5] *Valencia Declaration*; WMO Ibero-American Seminar on *Information Systems and Hydrometeorological* Forecasting, Valencia, Spain, end of March – beginning of April, 2004

[6] In the absence of the results of a workshop, this information was extracted from the report of a previous WMO *Flood Forecasting and Warning Workshop* held in Wellington, New Zealand, January 2002

[7] WMO Workshop on *Enhanced Flood Forecasting in Europe*, Bratislava, Slovakia, 12-14 December 2005

significant upgrading and strengthening of their basic data collection and transmission networks. In the latter, generally only a simple warning system for river water levels is operational.

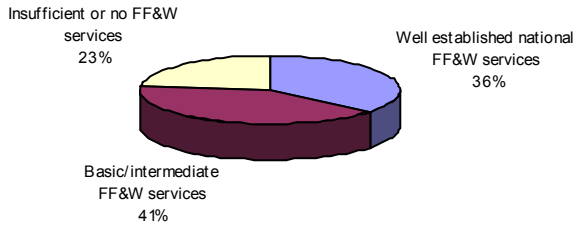
15. The region comprising the ***Mediterranean basin countries of RAs I and VI***[8] is constituted of different types of basins, varying from the longest river on Earth, the Nile, to catchments of very small surface area, variable discharge and short stream length. The latter type is that which causes most concern to NMHSs of the region as they are prone to flash floods. This combination of small catchments with intense and convective local precipitation makes it necessary to base flood forecasting on now-casting. The development of early warning systems based on automatic stations and radar, as well as close cooperation among NMSs and NHSs has therefore become necessary. While the most advanced countries in the region are pursuing this cooperation and have state-of-the-art technology, others have not yet established radar networks. Use is also made of rain gauges and rainfall runoff models when practical. A cause of concern in several countries, even the most developed ones, is the severe lack of qualified and motivated staff in both NHSs and NMSs, and in particular in weather and hydrological forecasting units. At a regional level, the status of hydrometeorological forecasting in the Mediterranean countries could be enhanced by the transfer of well organized information and flood forecasting systems such as the Spanish SAIH (or an adaptation thereof), or by cooperative initiatives such as the reinitiating of the MED-HYCOS project, the support of the BALWOIS project, and the promotion of a flood forecasting system for the Mediterranean and its sub-regions.

16. Based on the workshop reports and the sample of 86 country reports[9] presented, in ***Annex 2*** the main identified national flood forecasting issues and status have been summarized. It should however be noted that some of the statistics given in the table should be taken as *indicative (e.g.* on training and capacity building, institutional strengthening and coordination needs, etc.), since the level of detail of information provided in the country reports on these issues was not the same for all countries.

17. From a ***global perspective, Fig. 1*** provides information on the overall status of national flood forecasting activities in relation to the total of 86 reporting countries. The main symptoms for insufficient or non-existent national capabilities for flood forecasting are shown in ***Fig. 2***. However, for a number of countries (14 or 16%) hydrological forecasts are provided by a regional transboundary river basin authority. Furthermore, activities are underway to improve/modernize national flood forecasting and warning systems in 28 countries (33%), in some cases through technical assistance projects.

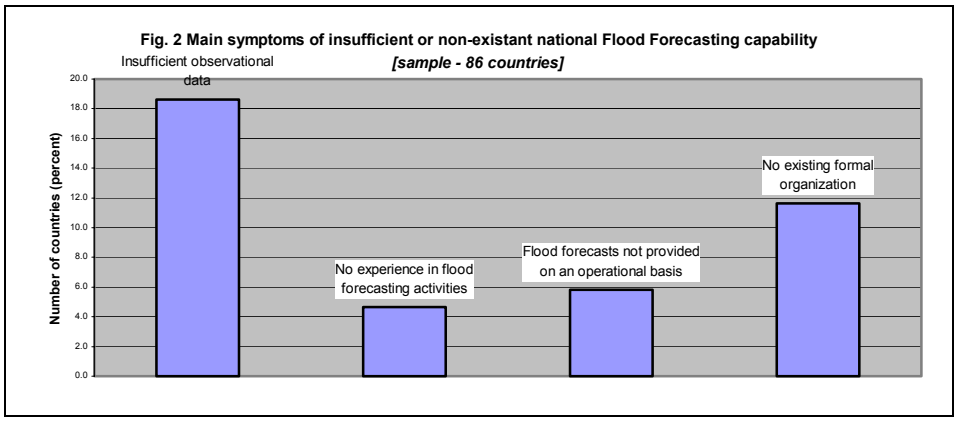
Fig. 1 - Overall Status of National Flood Forecasting and Warning (FF&W) Services

[sample - 86 countries]

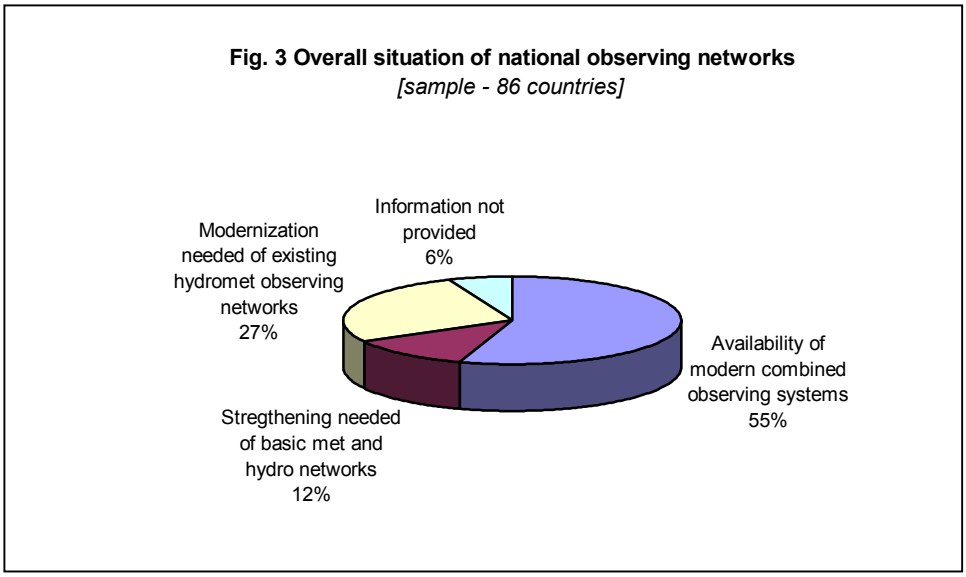


[8] *Zaragoza Declaration;* Expert Meeting on *Flood Forecasting in the Mediterranean Basin*, Zaragoza, Spain, 26 to 28 September 2006

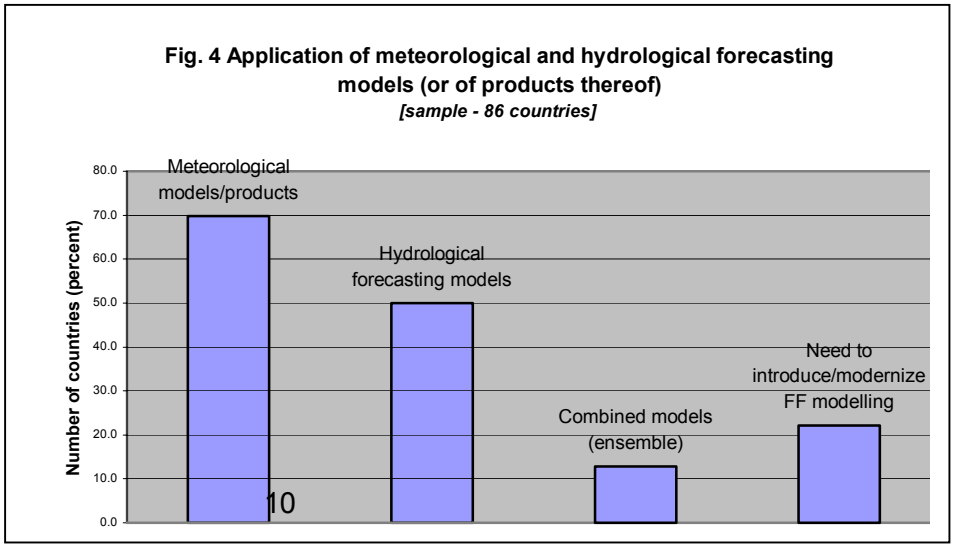
[9] The figures do not include countries of RA-V since no detailed information was available to allow a statistical analysis



18. As regards the existence of observing and information systems, the overall situation is shown in ***Fig. 3***. 47 countries (55 %) have available and/or make use of combined observing systems (automatic stations, radars, satellite imagery). On the other hand, in 10 countries (12%) a significant upgrading of the basic meteorological and hydrological networks for all general purposes is needed. In 23 countries (27%) modernization of the hydrometeorological observing networks with automatic data transmission and the telecommunications systems for flood forecasting purposes is identified as a requirement.



19. ***Fig. 4*** provides an overview with respect to the application of meteorological and hydrological forecasting models. To complement this information, it should be noted that in 24 countries (28%) national plans are underway to improve the forecasting models being applied, supported by capacity



building including staff training.

20. Finally, in 9 countries (10% of the total of reporting countries) there is a need for, or improvement of, institutional coordination agreements between NMSs and NHSs.

21. In summary, from a ***global*** perspective, it can be seen that the national flood forecasting and warning services have significant differences in terms of their levels of performance and outputs. In regard to flood forecasting and warning capabilities three broad levels have been identified:

- ***Level I*** - Flood forecasting and warning services are limited or not operational, and a significant upgrading and strengthening of the basic data collection and transmission networks is required. In these cases there is insufficient network coverage and data exchange to enable a sufficient amount of data for hydrological forecasting. Generally, there is very limited coordination between NMSs and NHSs, as well as weak dissemination of warnings to users. Some countries issue only qualitative weather forecasts and only a simple warning system for the main river water levels is operational when these reach critical values. This system is usually based on simple statistical methods and forecasts, if available, are disseminated by phone calls or radio.
- ***Level II*** - The basic infrastructures for flood forecasting and warning services are in place. However, upgraded data management procedures and improved methodologies and models for flood forecasting are required. In most cases, there is little experience in operational practice of advanced hydrological simulation and forecasting models. Regression or other simple models are generally used to forecast the peak of the water wave and approximate time of transit. In many cases, the level of coordination between NMSs and NHSs still needs to be strengthened
- ***Level III*** – These have well-established flood forecasting and warning services with high quality products and opportunities for further improvement through the use of new technology. The systems normally combine products and information from both meteorological and hydrological services. Different tools and methods are used to produce the flood forecasts and warnings (e.g. NWP, QPF, radar, satellite images, hydrological and statistical models and other approaches). Warnings generally are communicated through various media to Government and Civil Protection Agencies, industry and the public.

22. These broad levels have been stipulated in order to develop the proposed action and implementation plans (see ***Section 6.2*** below). Whilst these categories have been based on the analysis of the 86 countries survey, they are considered to adequately represent the broad range of situations in all countries.

3. Key Challenges for NMHSs

23. The main needs and requirements related to the overall *chain of hydrological forecasting components* that emerged during the regional workshops are summarized below.

24. The improvement of the hydro-meteorological observation and transmission networks is one of the most important concerns. As shown in ***Annex 2*** this may require a significant upgrading and rationalisation of the basic meteorological and hydrological networks for all purposes in many of the developing countries, or their modernization in others. An important aspect will be the harmonization/standardization of the equipment and measuring methods.

25. Upgrading/modernization of the existing data transmission and telecommunication systems are considered vital for flood forecasting purposes.

26. In order to make optimum use of data collection systems, improved data sharing mechanisms with inputs from various observation platforms and networks, within and among the countries, and the establishment of adequate national data collection and sharing mechanisms are other important considerations. Data and information on the performance of a flood forecasting and warning system also needs to be collected in the post event stage and provides a useful tool /basis on which to base future improvements.

27. With respect to the application of meteorological and hydrological forecasting models, there is a need to introduce/update operational modelling forecasting practices in a number of countries. In others there is a need for improvement of the forecasting models being applied. These improvements must be supported by capacity building including staff training, as required.

28. It was shown that the meteorological information required for flood forecasting needs to be quantitative, improved in quality and timeliness and risk-qualified (tailor-made forecasting). Products needed for now-casting services for flash floods are generally not available. This is also true in many cases in regard to the availability of medium-range and seasonal weather forecasting (MRWF), and in particular of precipitation (Quantitative Precipitation Estimation (QPE) and QPF).

29. Furthermore, one of the current weaknesses is that advanced methods and techniques including the use of Numerical Weather Prediction (NWP) products and ensemble forecasting techniques are not widely used in the meteorological and hydrological communities, as they are not readily available. Slightly over 33% of WMO Members have the capability/capacity to run NWP models and generate products.

30. Since hydrological models should be calibrated to the respective basin characteristics, there is no unique solution for all cases. In many cases, hydrological models have to be adapted to make use of the available (sometimes limited) meteorological inputs. While classical statistical, flood routing and some mathematical techniques and models do not require meteorological inputs of the kind discussed above, meteorological inputs are indispensable for flash flood situations and pre-warning services for the extension of lead-times for getting prepared for floods.

31. There is also a need for the development and application of climate prediction products in the preparation of seasonal river-flow outlooks.

32. A lack of trained human resources represents a crucial factor in forecasting. There is a need to strengthen the professional staff capabilities of NMSs and NHSs. In many cases the need was identified, not only for the familiarization of staff of NMHSs with current and new meteorological and hydrological forecasting systems and methodologies and the use of forecasting products - including climate outlooks - for disaster reduction, but also for training in basic meteorology and hydrology.

33. In certain countries there is a need for coordination and cooperation of activities between NHSs and NMSs. An institutionalised coordination and cooperation mechanism is required. Such a mechanism should clearly define the lines of responsibilities and rules and protocols for sharing of specific data and information. In some cases the organizational aspects of collaborative efforts also need to be addressed to improve flood forecasting in an integrated manner.

34. A need was also identified for the formulation of guiding materials in a number of subject areas for the improved cooperation between regional entities assigned the responsibilities in the areas of hydrology and meteorology. Preferably such guidelines should, amongst others, contain recommendations on good practice, institutionalisation of joint activities, harmonization and standardization of communication protocols and data formats, modelling and interpretation of results, and development of joint forecasting products prior to, during, and after the actual flood situations. In particular, flood risk mapping and assessment are fundamental pre-flood activities.

35. Storm surges pose a major hazard in many countries. However, operational and accurate storm surge forecasting and warning services are still rare. Therefore, a concerted effort needs to be made to further develop such systems and put them into operation.

36. Finally, limitation of financial resources is a major obstacle facing countries with weak flood forecasting systems. This is partly because the value of meteorological and hydrological data, information and products is still not adequately recognized and requirements prioritised. There is a need to continue to raise national awareness of, and to demonstrate the benefit of hydrological and meteorological data, information and forecasting services.

37. The key challenges (needs and requirements) for NMHSs identified during the regional meetings and in the country reports have been summarized in ***Box 2*** below***.***

Box 2 **- Key Challenges for NMHSs**

Establish the key requirements/needs for flood forecasting and warning and identify/quantify the benefits derived from (improved) flood forecasting services. Derived from this assessment, the major issues are:

a) Strengthening of observing and information systems

b) Promoting data exchange at national and international river basin levels

c) Improvement of meteorological forecasting practices and products

d) Improvement of hydrological forecasting practices and products

e) Strengthening of institutional coordination, cooperation and integration between NMHSs

f) Strengthening of cooperation and coordination of countries in issues related to flood forecasting and warning

g) Promoting training and capacity building in NMHSs

h) Formulating technical documentation and guidelines related to flood forecasting and warning

Complementary issues

i) Supporting disaster management

j) Addressing climate variability and change in the light of extreme events

k) Demonstrating the value of meteorological and hydrological data, information and products (including forecasts)

38. A separate **Supplement** to this document contains, amongst others, a summary of main conclusions/issues emerging from the Regional Workshops, as well as information on relevant country examples of good practice and opportunities through modern meteorological and hydrological forecasting practices in use by NMHSs.

Part B – Proposed Strategic Action Plan for Improved Flood Forecasting

4. Need for a Strategic Approach

39. Under a risk management approach, access to timely and reliable information and forecasts is critical for the application of appropriate response actions in cases of emergency. Improved data collection, continual model development, calibration and verification, etc., contribute to the improved accuracy of forecasts. A timely and reliable forecast depends not only on a sound quality-controlled data acquisition system but also on a set of multi-disciplinary (meteorology, hydrology, hydraulics, geo-mechanics, information systems and emergency management) collaborative inputs. Coordination and cooperation between meteorologists and hydrologists is essential to increase the lead-time, particularly in flash flood situations.

40. However, as described in ***Section 2*** of ***Part A*** many NMHSs at present do not have adequate means or the expertise to provide extended forecasting services in flood critical situations and to communicate effectively with disaster management authorities. Key challenge areas that need to be addressed have also been identified in ***Section 3***. Many of these challenges not only influence the flood forecasting services of the countries but also other areas such as water resources assessment, addressing the impacts of climate variability and change and the appreciation of the economic value of the services provided by NHSs. These issues are being addressed by the Hydrology and Water Resources Programme in collaboration with other WMO Programmes through various others activities. This proposed Strategic Action Plan therefore strategically concentrates on the areas of collaboration between the NMSs and NHSs.

41. A strategic approach is needed for NMSs and NHSs to strengthen their capacity to deliver better products making use of the state-of-the-art forecasting technologies through collaboration with a view to improve meteorological and hydrological forecasting products and services.

4.1 Objective of the Strategic Action Plan

42. The overall objective of the WMO Flood Forecasting Initiative, as stated in ***Box 1*** above, is to improve the capacity of NMSs and NHSs to jointly deliver timely and more accurate products and services required in flood forecasting and warning and to collaborate with disaster mitigation agencies active in flood emergency preparedness and response.

43. This is in line with the top-level objectives of the WMO Strategic Action Plan to produce more accurate, timely and reliable forecasts and warnings of weather, climate, and water and to improve the delivery of weather, climate, water and related services to the public, governments and other users. It is also one of the thrust areas of the WMO Commission for Hydrology. The Strategic Action Plan is designed to meet these objectives.

4.2 Expected Results of the Strategic Action Plan

44. The Strategic Action Plan at this stage is concentrating on the first three expected results of the WMO Flood Forecasting Initiative listed in ***Box 1*** above. Thus, at *national level* this would assist NMHSs in coping with their changing role in disaster risk reduction by means of a comprehensive forward-looking plan for the upgrading, modernization and strengthening of their flood forecasting and warning activities.

45. At the *regional level* such a strategic approach would permit the evolution of a framework under which partnerships and development assistance could be provided and coordinated amongst the Members and the various contributing agencies while taking advantage of existing regional and international arrangements.

46. The focus and direction of the proposed strategic approach is not only directed to the needs of the developing world but the Strategic Action Plan also addresses requirements of well-established flood forecasting and warning systems for their further improvement through the development and use of new technology. Fully implemented this will result in more efficient, effective, robust and resilient flood forecasting and warning systems.

4.3 Outcomes

47. The implementation of the Strategic Action Plan will help in:

- Needs-driven development of operational flood forecasting and warning systems.
- Increased sharing of data and information at national, regional and international levels.
- Improved weather forecasting products for hydrological purposes.
- Optimised hydrological flood forecasting based on the effective use of available meteorological and hydrological data and information.
- Enhanced regional integration of meteorological and hydrological forecasting services, including the production of regional climate/hydrological outlooks.
- Increased attention to, and effectiveness of, transboundary river basin flood forecasting and warning.
- The development of standards and norms, to contribute to the homogenisation of regional flood forecasting and warning activities, such as standardization of measuring procedures and protocols for processing, model sharing and dissemination of data.
- Implementation of regional flood related projects as defined in the Strategic Action Plan.
- Strengthened technical cooperation among developing countries, as well as technology transfer from developed countries.
- Complementary research and product development in the field of meteorological and hydrological forecasting.
- Mobilization of resources through national mechanisms, as well as regional and international efforts.
- Improved understanding of the benefits and costs of flood forecasting and warning systems.
- Development of multi-criteria approaches to prioritisation of system needs.

5. Opportunities and Possible Actions

48. The proposed Strategic Action Plan has been developed on the basis of the outcome of the series of regional workshops/expert meetings held under the WMO Flood Forecasting Initiative (described in ***Section 2*** and ***3*** of ***Part A*** above), with the view of addressing the identified key challenges for NMHSs summarized in ***Box 2***. It was subsequently adopted during Synthesis Conference held during November 2006. As can be seen, the proposed steps identified for each of the key issues comprise various levels of action, ranging from very basic requirements, through an intermediate level, to those of high sophistication or advanced technical development. The national implementation of the proposed actions will depend in each case on the level of development and on a specific requirement (and its priority) of the corresponding national Services.

5.1 Core Solutions in the Frame of the WMO Flood Forecasting Initiative

5.1.1 Strengthening of Observing and Information Systems

49. Well-functioning modern observing networks, real-time data transmission and hydro-meteorological information systems are basic elements for an effective flood forecasting system. Their effectiveness will depend upon good coordination between NMSs and NHSs.

50. A good mix of automatic and manned stations will ensure continuous observations. Radar-based observations coupled with ground based rainfall observation networks are of high value for modelling and flood forecasting and also nowcasting. Likewise satellite information – in particular for Quantitative Precipitation Estimation and information on flooded areas – provides the opportunity of access to additional valuable information.

51. Runoff from ungauged catchments or those with limited network coverage or deterioration of observing networks can significantly reduce the accuracy of forecasts and therefore in some instances requires major attention. It is anticipated that in the future, more and improved radar and satellite based products will be generated to cater for the needs of catchments with minimum-density terrestrial networks.

52. Finally there are international projects, such as those under the aegis of WMO WHYCOS that assist NMSs and NHSs in strengthening their data collection, processing and dissemination activities and contribute to their capacity building. These projects offer the opportunity for also assisting the participating countries in improving their flood forecasting activities.

Box 3 –Actions [10] ***recommended for the strengthening of observing and information systems***

a) Based on objectives-driven data requirements, develop and implement plans, including, as required, network re-design (raingauges and river gauges) and appropriate real-time data transmission, to achieve a significant upgrade and strengthening of the *meteorological* and *hydrological* networks for flood forecasting. Integration with general purpose networks may be required.

b) Plan the establishment of reliable and, if possible, redundant real or near real-time data transmission systems for flood forecasting purposes within a country, among institutions and agencies, and among countries as required, especially taking into account transboundary needs.

c) Ensure that the instruments selected for equipping observing stations and for data communications are in compliance with WMO standards and regulations and are appropriate for and capable of being operated and maintained by the NMHSs and suitable for operation in the environment in which they are required to work. Ensure that adequate training of all staff is provided. Emphasis should be placed on the importance of ongoing station maintenance including the provision of adequate staffing of the operation of these stations.

d) In the national context, recipient countries of externally funded projects need to ensure compatibility and inter-operability of appropriate technologies used in network operation, while donor countries should coordinate their actions through appropriate mechanisms and programs such as WMO's Volunteer Cooperation Programme (VCP).

[10] National implementation of the proposed actions will depend in each case on the level of development or a specific requirement of the corresponding Services.

e) Periodic reviews, assessments and revisions of hydrological networks need to be included in operational and maintenance procedures to ensure that high quality measurements of the observed variables are available for flood forecasting purposes.

f) Prepare and implement plans to evaluate the need for, and benefit of, establishment, and /or modernization or upgrade of meteorological radar networks, allowing for different information systems (radar and rain gauges).

g) Encourage the development of improved techniques for the estimation of observed rainfall from satellites to provide improved observation coverage in remote and poorly instrumented river basins.

h) Take steps to periodically assess, adapt and/or adopt new emerging observing technologies including the required training.

i) In parallel with the upgrade of networks, put in place mechanisms to improve quality of measurement and accessibility of data, particularly during extreme events, and to implement or further develop established data quality control procedures.

j) Promote and provide support to WHYCOS components and other regional and national projects geared to the strengthening of the national observing systems with flood forecasting as one of the application objectives.

k) Take appropriate steps to ensure the continuous maintenance and sustainability of observing networks.

l) Where necessary, there should be a close collaboration in the design of hydrometeorological networks.

m) With the assistance of WMO Regional Associations where required, assess the possibility of donor support to establish a fund for network maintenance for those countries in need of such support. The benefits of support from appropriate technology providers (e.g. mobile telephone network operators) should be investigated.

n) Countries should, as required, strengthen joint networks and national systems of hydrometeorological information by means of an adequate co-ordination at highest level between the NMSs and NHSs in their corresponding WMO Regions.

o) WMO should assist efforts to improve the status of hydrometeorological forecasting in the Mediterranean countries, such as the reinitiating of the MED-HYCOS project, support to the BALWOIS project, and promotion of a flood forecasting system for the Mediterranean and its sub-regions. *[WMO RAs I and VI]*

5.1.2 Promoting Data Exchange at National and International River Basin Levels

53. In many countries, national, provincial/state or local Governments or the private sector operate real-time data networks to support their individual needs and, in many cases, these data are not shared. Coordination and data sharing can significantly augment the amount of data available for all organizations. It has the potential to increase forecast accuracy and in addition makes better use of financial resources. The philosophy of value from data collected once used many times applies in this instance. Coordination mechanisms, common data and metadata standards offer the opportunity for a more efficient exchange of hydro-meteorological data and information from different agencies, not only nationally but also at the international level.

54. This issue is addressed by WMO Resolutions 25 (Cg-XIII) “Exchange of hydrological data and products”, and 40 (Cg-XII) “WMO policy and practice for the exchange of meteorological and

related data and products including guidelines on relationships in commercial meteorological activities". Member countries should adopt these resolutions in their policies for sharing data, both within the countries and with other countries. Accordingly, NHSs and NMSs may align their data collection and exchange policies, in particular as regards meteorological and hydrological data as input to flood forecasting models.

55. Once data have been observed at sites, they must be transmitted to locations where they can be stored, accessed and used. Meteorological and hydrological data are needed in near real time so that NMHSs can produce up-to-date and reliable forecasts. Many countries use the WMO Global Telecommunication System (GTS) for the transfer of real-time meteorological data. A recent development in this context is the WMO Information System (WIS) [11] – a single coordinated global infrastructure that is intended to serve all relevant WMO programmes and other users. WIS supports the use of different types of communication links as available for transmission and dissemination of data and information.

56. On-line communication channels and facilities between the NMS and the NHS, such as direct computer links, communication networks and the adoption of pro-active information exchange systems offer the opportunity to ensure easy access and exchange of meteorological and hydrological data, products and information.

Box 4 –Action [12] ***recommended for promoting data exchange at national, international and transboundary river basin levels***

a) Align policies in the area of data exchange, in particular meteorological data as input to flood forecasting and meteorological models, to the WMO Resolutions 25 (Cg-XIII) and 40 (Cg-XII).

b) Take steps to establish or strengthen cooperation and coordination in issues related to real-time and historical data exchange at the national, international and transboundary river basin levels.

c) Establish or strengthen international agreements on data exchange of any type, but in particular radar data in border areas where the radar range may be useful for neighbouring countries, in order to provide the areal coverage or overlap of echoes, with the aim of improving flood forecasting in those regions. If possible, there should be a joint regional establishment of a radar networks.

d) Design and establish adequate data collection and sharing mechanisms, based on inputs from various observation platforms and networks.

e) Develop a standardized approach to ensure data compatibility, e.g. data coding, format, base standards for exchange of distributed, grid and similar data for facilitating data management and visualization, and exchange and dissemination of current and new types of products.

f) Develop and establish communication systems to allow inter-operability of present-day hydrological and meteorological data communication systems, such as direct computer links, on-line communication networks and the adoption of pro-active information exchange systems.

g) Consider, as required, the use of the WMO Information System to service the needs of both a meteorological and hydrological nature.

[11] See description in Web: http://www.wmo.int

[12] National implementation of the proposed actions will depend in each case on the level of development or a specific requirement of the corresponding Services.

h) WMO should urge NMHSs to establish and exchange metadata to enable greater insight into data availability and access.

i) WMO should look for innovative methods of transferring well organized information systems and flood forecasting systems such as SAIH[13] (or an adaptation thereof) to other Mediterranean countries, for example through pilot projects. *[RA-I/VI]* DEMO PROJECT.

5.1.3 Improvement of Meteorological Forecasting Practices and Products

57. Advances in the development and use of products available from NMSs such as Numerical Weather Prediction (NWP), Quantitative Precipitation Estimation (QPE), Quantitative Precipitation Forecasting (QPF), Medium Range Weather Forecasting (MRWF), as well as the application of "Ensemble" prediction techniques, constitute important opportunities to improve the lead-time and increase the reliability of flood advisories and warnings. In this context, NMSs are coming under increasing pressure, not only to meet the present obligations concerning the provision of weather information and services, but also to confront the challenges posed by extreme events.

58. A number of NMSs are carrying out NWP and there is a growing interest and opportunity for WMO Members to obtain access to NWP products and use these as a component to improve flood forecasting products. There is need to promote bilateral and regional cooperation to deliver derived NWP products and further use them at local level.

59. QPE and QPF offer the opportunity to improve flood warning lead-times and accuracy. The increasing availability of remotely sensed and derived observational data from radar and satellite systems and improved modelling capabilities have improved access to, and potential use of QPE and QPF. Better access to real-time rainfall has provided an improved capability to ground-truth remotely sensed data, and new systems will provide higher resolution and thus improved outputs. Ensemble Prediction Systems (EPS) for mid-term forecasts, with a probabilistic output, are very useful for the decision maker.

60. An improved quantitative understanding of local atmospheric processes, in combination with improved prediction of convective processes and Quantitative Precipitation Forecasts greatly facilitate the now-casting capability of flash floods. This requires improved terrestrial and satellite-based observing networks together with advanced data assimilation capabilities and correction algorithms for precipitation estimates. In this regard, the potential of tools of an international nature such as the software application of the Satellite Application Software (SAF) of now-casting from EUMETSAT, the TRMM satellites and others, constitute opportunities worth considering, particularly as an alternative to the development of radar networks in those countries where their implementation is currently not realistic.

61. However, hydrologists should recognise and be aware of the limitations, in particular as regards the forecasting of precipitation fields, of the currently available meteorological data and products and make the best use of them to achieve flood forecasting objectives. Likewise, meteorologists need to understand information that is needed by NHSs and disaggregate precipitation forecasts from the regional or national level to basin level.

Box 5 –Action [14] ***recommended for the improvement of meteorological forecasting practices and products***

[13] SAIH is an integrated information system used in Spain, where hydrologic, hydraulic and meteorological data are collected in real time and transmitted to the corresponding decision centre to be processed and applied to the solution of water resources management problems.

a) NMSs should take into account the hydrologists' needs in terms of meteorological forecasts for a closer integration of meteorological inputs in flood forecasting. This may require meteorological training courses to include some elements of hydrological training.

b) Develop or continue the development/improvement of meteorological techniques particularly for hydrological forecasting purposes, in particular those of QPE and QPF.

c) Promote bilateral and regional arrangements to deliver derived NWP products for further use at local level.

d) Promote the use of MRWF on an operational or semi-operational basis for hydrological forecasting purposes.

e) Continue improvement of the meteorological models and nowcasting products, both deterministic and probabilistic, particularly in relation to high intensity rainfall.

f) Provide advice to NHSs, through specialized meteorologists in the field of forecasting, particularly in the following areas: radar and satellite image interpretation, use of forecast models in the field of now-casting, rainfall forecasts, both deterministic and probabilistic uncertainties and most frequent errors of meteorological models.

g) Provide advice to NMSs and NHSs on aspects of downscaling, bias correction and calibration of NWP forecasts to specific locations and river catchments to assist hydrologists to obtain the best possible information from the limited skill of NWP models in QPF.

h) Study and undertake downscaling of global models for areas of complex topography, aiming at improvement of the spatial and temporal location of the convective phenomena that produce large quantities of precipitation in very short time intervals.

i) Continue further development of calibration techniques for radar and satellite derived rainfall data.

j) Consider as required the application of tools of an international nature such as the software application of the Satellite Application Software (SAF) of now-casting from EUMETSAT, the TRMM satellites and others.

k) WMO should promote and organize efforts including case studies to study the role of NMHSs in addressing the problems associated with forecasting of floods that result from snowmelt, ice jams, glacier lake outbursts and landslides. The International Polar Year (IPY) may provide one opportunity for such initiatives.

l) Develop and make available state-of-the–art NWP products and techniques from meteorological services, RSMCs and other centres o excellence for application by NHSs.

m) Continue the development of hydrological ensembles coupled with hydrological models for improving long-range hydrological forecasting and decision-making under uncertainty.

n) Develop decision-support systems to assist local authorities, civil protection agencies, etc. in taking the necessary preventive measures.

o) WMO include in its future plans actions to improve the capacities of NMSs for developing meteorological products for flood forecasting, particularly QPF and probabilistic Quantitative Precipitation Forecasting. *[RAs I-VI]*

[14] National implementation of the proposed actions will depend in each case on the level of development or a specific requirement of the corresponding Services.

p) NMSs pertaining to a certain WMO Region to consider developing jointly, as required, the relevant products for hydrological use in through enhancing their capability in QPF, use of available technology such as ensemble products, and NWP to guide QPF forecasts. *[RA I, SADC]*

q) WMO, with the support of members of Regional Centers, to assist in arranging the distribution, possibly free of charge, to the NMHSs of the countries (as required), of the products generated by the European Centre for Medium- Range Weather Forecasting (ECMWF). In addition, such arrangements are also to be sought with other European Agencies in which members of Regional Centers participate, in particular EUMETSAT. *[RAs III/IV]*

r) WMO to promote and support the international exchange of research addressing the improvement of intense rainfall forecasts in the Mediterranean basin, through projects such as MEDEX. *[RAs I-VI.* This action should be extended to all member countries that would require such assistance.*]*

5.1.4 Improvement of Hydrological Forecasting Practices and Products

62. As outlined in **Box 2** above, the establishment of an effective flood forecasting and warning and response system, amongst other factors, depends on a thorough analysis of existing forecasting capabilities and on the identification of key users and their information needs. The adoption of a multidisciplinary approach in all flood forecasting related activities, in particular by including inputs from civil protection experts in the forecasting system development, offers an opportunity to increase flood forecasting effectiveness.

63. In order to produce a flood forecast there should be a hydrological modelling capability that uses the available meteorological and hydrological real-time data. Models vary in complexity, accuracy and ease of use. There is no unique solution for all cases, since models have to be adapted to the characteristics of each river basin being studied and the level of flood risk. There are a large number of public domain and proprietary computer programmes available for use in flood forecasting. The final selection will depend on the available data, basin characteristics, cost, complexity, capabilities and the needs of the user community.

64. There is a high demand for hydrological products and services that take into consideration possible future conditions (especially rainfall). The increasing availability of remotely sensed and derived observational data from radar and satellite systems have improved hydrologists' access to, and potential use of QPE and QPF. Hydrological models can also be updated in real-time using information also provided in real-time (such as soil moisture, evaporation, etc.).

65. Better access to real-time rainfall provides an improved capability to ground-truth remotely sensed data, and thus improved outputs for use by the hydrological community. Hydrological models are also improving and once combined with QPE and QPF can also produce high quality operational products.

66. Uncertainty in the estimate of QPF is a key issue and one that can now be addressed by using ensemble forecasting techniques. For pre-warning services stochastic and ensemble techniques are useful when used in combination with a threshold concept to switch from probabilistic to deterministic forecasting. The value of forecasting information is increased significantly if presented together with an associated uncertainty assessment, particularly if used with a decision support system.

67. Available hydrological modelling techniques for extension and interpolation of hydrological data can sometimes address the needs in areas where the network is inadequate. Furthermore,

gaps in historical time series of hydrological and meteorological data, which are essential for calibrating models, can sometimes be infilled through such techniques.

Box 6 –Action [15] ***recommended for the improvement of hydrological forecasting practices and products***

a) Prepare detailed national consolidated requirements assessment as a basis to jointly develop NMS and NHS tailor-made forecasting products.

b) Plan and implement improvements in flood forecasting systems through the use of new technologies with high quality estimation and forecast products.

c) Take steps to strengthen or upgrade, as required, the application of data management and data assimilation procedures and improved methodologies and models for flood forecasting.

d) Define and assess the NHSs' needs in terms of meteorological forecasts, with a view to integrate meteorological inputs in flood forecasting.

e) Develop and adapt hydrological models that suit the user needs as well as the characteristics of the river basin and level of risk, as no single solution applies to all circumstances.

f) Exchange software and data/information for hydrological forecasting and prediction.

g) Provide professional guidance to other NHSs that are developing their flood forecasting abilities and skills in the selection, adaptation, calibration and use of hydrological models to suit operational requirements.

h) WMO to promote the application, as required, of remote sensing information for flood forecasting.

i) Undertake, as required, storm surge modelling activities, possibly in collaboration with other countries of regions that are similarly affected.

j) Efforts should continue to be made to use the probabilistic forecasts from the ensemble prediction systems that will produce different scenarios such as: most likely scenario and extreme scenarios.

k) Continue the development of meteorological ensembles coupled with hydrological models for improving long-range hydrological forecasting and decision-making under uncertainty. These should feed directly into decision support tools.

l) Expand the forecast products' provision to include long-range hydrological forecasting through regional climate centres, noting the limitations of such products.

m) Develop/improve hydrological modelling for extension and interpolation of hydrological data needs in areas where the networks are inadequate, recognizing that there will be limitations to our capabilities.

n) Develop decision support systems to assist local authorities, civil protection agencies, etc. in taking the necessary preventive measures.

o) Consider and ensure the participation and involvement of local communities in activities related to hydrological forecasting and warning.

[15] National implementation of the proposed actions will depend in each case on the level of development or a specific requirement of the corresponding Services.

p) Promote steps in filling gaps in historical time series of hydrological and meteorological data and ensure rescue of historical data.

q) Promote steps in using data assimilation in hydrologic models, including, amongst others, soil moisture and stage data.

r) Promote the collection of real time data for flood forecasting purposes.

s) Provide guidance for the development of performance monitoring of flood forecasting systems and floodplain mapping and for addressing specific issues such as flash floods and extreme events.

t) Countries are encouraged, with WMO's support, to participate actively in the EUMETSAT SAF-Hydrology project to strengthen capabilities in the use of satellite technology. *[RAs I/VI]*

u) WMO to include in its future plans actions to support development and outreach activities between NHSs on effective methods to incorporate probabilistic products into their hydrological forecasting, when possible. *[RAs I/VI], [RAs III/IV]*

v) In the case of design and implementation of technical assistance projects with external funding for new or upgraded national flood forecasting systems, it should be ensured that the relevant characteristics of the basins are addressed, the actual capabilities of the receiving country are taken into account, that the training of staff and the maintenance costs of the system are adequately considered and, above all, that the project will be sustainable once the external funding has ended.

5.1.5 Strengthening of Institutional Coordination, Cooperation and Integration between NMSs and NHSs

68. A legal and regulatory framework is an essential prerequisite for an effective flood forecasting system. The issuing of administrative and organizational rules and regulations from the viewpoint of forecasting services is an important development process in many countries. These constitute important opportunities to improve the efficiency and effectiveness of forecasting services to the public. Thus, there is need for an institutional coordination, cooperation and integration with regard to flood forecasting and warning activities between NMSs and NHSs in terms such as: lines of responsibilities, sharing of specific data, and provision of forecasts and information.

69. First is the fundamental question of hydrological and meteorological *coordination*. In many countries one or more agencies may operate meteorological forecast networks, while hydrological networks are the responsibility of entirely different agencies or departments. The successful development and operation of a flood forecasting system depends very much upon cooperation among these various meteorological and hydrological agencies.

70. Secondly, a close *cooperation* between meteorological and hydrological forecasters and their respective organizations, besides being absolutely necessary for the preparation of timely and reliable flood forecasts, is also beneficial for both communities: NHSs make use of the data and meteorological forecasts to better define the entry parameters for their models, particularly in the field of rainfall; NMSs gain from the feedback from one of the fundamental users of their data and information, which increases or highlights the socio-economical value of their activities. Furthermore, it is important that the cooperation between meteorologists and hydrologists be expanded to the civil protection agencies that manage the emergency situations related to floods.

71. Third, the necessary *integration* of flood forecasting efforts provides an opportunity for meteorological and hydrological staff to work together. There is need to expose hydrologists to operational meteorological forecast activities (possibly through their attachment to NMSs), and meteorologists to flood forecasting operations, so as to achieve a meaningful desired integration.

Box 7 –Action [16] ***recommended for strengthening of institutional coordination, cooperation and integration between NMSs and NHSs***

a) Review the issue of administrative and legal reforms required for improved institutional arrangements for flood forecasting and warning operations in a national context, in relation to: lines of responsibility, sharing of specific data, and provision of warnings and information and propose/develop guidance material on this topic for the use of NHSs and NMSs.

b) Develop a checklist of common areas of cooperation between the NMSs and NHSs and establish areas of responsibility in terms for flood forecasting, as well as with corresponding civil protection agencies and others involved in disaster mitigation.

c) Develop a standardized communications and operation terminology for meteorologists and hydrologists in flood forecasting and flood risk management (selected terminology) with a view to communicate to this to users in an effective and understandable manner.

d) Establish guidance for enabling involvement of all stakeholders in the development and operation of flood forecasting services, especially at the community level.

e) Expose hydrologists to operational meteorological forecast activities and meteorologists to flood forecasting through attachments and secondments.

f) Establish joint working groups of hydrologists and meteorologists to work on the development of new methods and technologies of forecasting (e.g. improvement of flash flood forecasting).

g) Promote and encourage dialogue, cooperation and exchange of expertise between the meteorological and hydrological communities by encouraging establishment of institutions, societies or bodies that bring together meteorologists and hydrologists.

h) Develop a policy of closer collaboration between the NMHSs and academia to maximize mutual benefits from the exchange of information, data, studies and research.

i) Ensure that hydrologists and meteorologists participate equally in relevant meetings organized for flood forecasting and warning purposes.

j) Encourage NMSs and NHSs to issue joint bulletins.

k) Continue the organization of fora, under the WMO Flood Forecasting Initiative, for strengthening of institutional capacity of countries and allowing continuous dialogue and exchange of experience in the field of flood forecasting and warning. As required, these mechanisms should be transferred to other regions and member countries.

5.1.6 Strengthening of Cooperation and Coordination among different Countries in issues related to Flood Forecasting

[16] National implementation of the proposed actions will depend in each case on the level of development or a specific requirement of the corresponding Services.

72. Flood forecasting in trans-boundary river basins requires cooperation between institutions of riparian countries within the basin. A number of transboundary basins are covered by treaty, international agreement or other institutional arrangements[17], which provide opportunity for collaboration in flood forecasting and warning. Regular exchange of data and information between countries, especially during flood events, provides an important opportunity for improving flood forecasting and Warning in shared river basins.

73. Effective communication links need to be maintained between relevant institutional infrastructures to support international cooperation for the generation of transboundary flood forecasts. Another dimension of regional collaboration is exchange of expertise for improving tools and methodologies for weather and flood forecasting and development of regional training programmes.

74. These river basins also provide an opportunity to foster twinning agreements between NMHSs with the objective of sharing knowledge, experience and technology, improving cooperation and enabling the development and use of advanced forecasting products and their dissemination.

Box 8 – Action*[18] *recommended for strengthening of cooperation and coordination between countries on issues related to Flood Forecasting

a) Promote dialogue between NMSs and NHSs with a focus of improving tools and methodologies for weather-and flood forecasting including workshops.

b) Foster twinning agreements between NMSs and NHSs with the objective of sharing know-how and technology in improved cooperation and use of advanced forecasting products.

c) Set-up focal points between riparian states of an international basin for flood warning systems, for alerts and generation of awareness and provide a platform for their regular interaction.

d) Encourage and promote close links between hydrological, meteorological and civil defence groups and services within the countries at the basin level.

e) Establish agreements for the provision of flood forecasting and warning services at regional/catchment levels as required.

f) Promote access to NWP products, observations and hydrological forecasts between countries sharing the same river basin.

g) Establish networks using a cascade of information from the global level through regional and catchment based groups in the developing countries, in a similar manner to the project on severe weather forecasting and warning, to enable support to the developing countries in flood forecasting and warning.

h) WMO and international river basin organization to also consider support to those countries where international rivers represent only a minor share of the total of their water resources so as to also strengthen their national for flood forecasting and warning activities and allow them to benefit from participating in international river institutions' activities. *[RA I]*

[17] *Overview Situation Paper on Flood Management Practices*; WMO/GWP Associated Programme on Flood Management; Technical Support Unit, 2004

[18] National implementation of the proposed actions will depend in each case on the level of development or a specific requirement of the corresponding Services.

i) Latin American countries, as required, to strengthen their joint networks and national systems of hydrometeorological information by means of an adequate co-ordination at highest level between the NMSs and NHSs. *[RAs III/IV]*

j) WMO should also consider possibilities of assisting the Sava River countries (Albania, Bosnia and Herzegovina, Croatia, Serbia, Montenegro and Slovenia) in implementing the Sava Initiative for improving their forecasting systems. *[RA-VI]*

k) Countries concerned, with the assistance of WMO, consider the strengthening of the Drought Monitoring Centre (DMC) of SADC countries to address hydrological forecasting needs. *[RA I SADC]*

5.1.7 Promoting Training and Capacity Building in NMHSs

75. Trained and skilled staff are essential for the implementation of flood forecasting activities. It is well recognized that human input in flood forecasting activities is very important and cannot always be overcome through the use of advances in technology. It is therefore crucial to ensure, through capacity building, that staff are appropriately resourced and skilled, and can thus contribute to the advancement of NMHSs.

76. In response to the rapid changes in technology and the social, political, economic and legal framework under which individual NMSs and NHSs are operating - in addition to the global environmental challenges – they need to have qualified and trained manpower and adequate facilities.

77. Besides training in the fields of meteorology and hydrology, capacity building should also comprise, as required, recruitment and retention schemes and an enabling environment for staff; career development; provision of necessary equipment and tools; and the assessment, adaptation and adoption of new emerging technologies.

Box 9 –Action [19] ***recommended for promoting training and capacity building in NMHSs***

a) Identify staff training requirements as regards meteorology and hydrology, particularly in flood forecasting, and prepare and implement long-term proposals to address these needs.

b) WMO to plan and execute capacity building programmes that include training activities for meteorological and hydrological forecasters, so that they acquire a wider and up-to-date knowledge of modern tools for monitoring, forecasting, communicating information and emergency management and disaster preparedness in general.

c) WMO to review and periodically revise the training programmes (both regional and national) aimed at providing NMSs and NHSs staff at different levels with advanced technology, so as to meet the challenge of emerging technology. Training should be targeted at more than one level of capability and provide appropriate knowledge and advice relevant to the level of development and capability of the agencies involved. .

d) Provide training on hydrologic data assimilation techniques, methods to communicate and express uncertainty, interface techniques between meteorological inputs and hydrological models, and advantages and weaknesses of radar applications for hydrological purposes.

[19] National implementation of the proposed actions will depend in each case on the level of development or a specific requirement of the corresponding Services.

e) Plan and undertake capacity building activities and the development/adaptation/ improvement of hydrological forecasting models, in cooperation with local universities and research communities and regional agencies.

f) Plan and provide training for the development of user-oriented products.

g) WMO to assist in the organization of regional training activities as required, including roving seminars with the services of experts from within the corresponding WMO Region.

h) Ensure regular budget allocations for staff training and continuing education.

i) Encourage WMO to continue to assist training of staff of NMHSs in developing countries and developed countries, for example, by promoting and supporting temporary staff secondments.

j) Ensure that following training, participants are provided with the data, information, software, hardware and other tools necessary to implement the training in their own organisations.

k) Develop a specific educational//training package targeted at flood forecasting related to the occurrence of tropical cyclones.

l) Use pilot projects to support capacity building and education opportunities in relation to flood forecasting.

5.1.8 Formulating Technical Documentation and Guidelines related to Flood Forecasting

78. Technical documentation, such as the WMO Technical Regulations, the Guide to Hydrological Practices and the Manual on Flood Forecasting and Warning can play an important role in improving cooperation not only between NMSs and NHSs, but also with regional bodies and organizations. The ease of sharing such guidelines with the availability of the Internet and distance learning facilities provides an opportunity in implementation of such guidelines in countries which are planning to improve their flood forecasting.

79. Technical documentation and guidance could, amongst other material, contain, as required, recommendations on the establishment of joint activities between agencies under a legal or other framework, harmonization and standardization of communication protocols and data formats, choices in processing procedures, modelling and interpretation of results, dealing with probability and uncertainty in forecasting, development of joint forecasting products, clear identification of the roles and responsibilities of NMHSs during pre-warning times and actual flood situations and performance monitoring.

80. The preparation of relevant guidance material is also closely linked with the proposed undertaking of demonstration projects (see ***Section 6.3*** below).

Box 10–Action [20] ***recommended for the formulation of technical documentation and guidelines related to Flood Forecasting***

a) Prepare guidelines for the dissemination of flood forecasting products to include probability statistics aimed at enhancing their utility for end-users.

b) Compile documentation on the effects of flooding to help amongst others demonstrate to decision-makers the benefits of a flood forecasts.

c) Undertake a compilation of regional experiences in the use of improved techniques for meteorological modelling, including QPE and QPF, for flood forecasting.

d) Make available documentation on the state of development of ensemble forecasting techniques related to flood forecasting.

e) Develop guidelines for data quality control and management associated with flood forecasting (including the evaluation of forecast accuracy).

f) Case studies should be used in guidance material to demonstrate best practice in flood forecasting.

5.2 Complementary Aspects to Facilitate the Implementation of the Possible Solutions

5.2.1 Supporting Disaster Management

81. Countries are now starting to recognize the importance of dealing with floods in the context of *Integrated Flood Management* (IFM)[21]. This is an approach that integrates land and water resources development in a river basin and advocates the need for a balanced approach to optimise the beneficial effects while minimizing the disastrous effects of floods. In the context of flood management an integrated, cross-sectoral approach based on risk management principles ensures that the vulnerability of the society is addressed by preparedness and timely and reliable early warning systems.

82. Flood forecasting has now been well recognized as an essential tool in flood management, and therefore should be appropriately integrated into the overall framework of flood hazard and impact management. NMSs and NHSs have an important role to play in the core functions of disaster management and mitigation. These may comprise hazard identification, reviewing risk assessments, and the communication of hazards through forecasting. Tailor-made forecasting is indispensable to enable users to make maximum use of forecasting information. Advanced seasonal prediction capabilities of high tropical cyclone activity, or prolonged heavy rainfall also provide valuable tools for longer-term planning purposes in many countries.

83. A multi-hazard approach in terms of observation systems, telecommunications and the development and communication of forecasting products is recognised as essential in implementing the contributions of NMSs and NHSs towards disaster management. Such an approach offers the opportunity of synergy effects arising from the common use of observation

[20] National implementation of the proposed actions will depend in each case on the level of development or a specific requirement of the corresponding Services.

[21] *Integrated Flood Management*; World Meteorological Organization and Global Water Partnership; APFM Technical Document No. 1, second edition, edited by the Technical Support Unit, 2004

and telecommunication infrastructure, personnel and channels and mechanisms for flood forecasting and warning.

84. During the workshops, disaster management issues were addressed in a rather marginal form, and therefore not many specific actions or recommendations were made in that regard. Therefore, it was felt necessary to also include other actions related to this subject, extracted from the RA II Strategy Document[22], to complement requirements in relation to supporting disaster management.

Box 11–Actions [23] ***recommended for supporting disaster management***

a) Link forecasting services to socio-economic factors including the development of a standardized methodology for damage assessment.

b) Promote the development of standardized methodologies for impact and damage assessment and information linked to hydrologic forecasting services.

c) NMHSs should be actively involved in the national emergency/disaster response system.

d) Consider strengthening the role of NHSs in disaster management by including other specific related functions, such as hazard identification, risk assessment, reviewing risk assessments, and communication of hazards through forecasting, in their functions.

e) Chose and establish a multi-hazard approach in terms of observation systems, telecommunications and the development and communication of forecasting products, ensuring a close cooperation between NMSs and NHSs.

f) Re-enforce links with national disaster managers, also ensuring close collaboration/interaction with other institutions, and possibly including the participation of the affected community.

g) Develop common regional warning Internet websites for meteorology/hydrology information for disaster risk management.

h) Develop risk-qualified hazard maps, including coastal maps in a way that these can be easily visualized for the target group, so as to make flood forecasting and warning more meaningful for communities.

i) Promote public education and awareness with regard to flood maps and flood management.

j) Develop decision support systems to assist local authorities, civil protection, etc. in taking the necessary preventive measures.

k) African countries concerned to study and undertake accordingly a realistic reorganization of the ORSEC (disaster relief organization) plans in place, so as to bridge gaps and rectify weaknesses, through awareness-raising amongst the various stakeholders, capacity-building. *[RA-I]*

5.2.2 Addressing Climate Variability and Change in the Light of Extreme Events

85. Climate change and climate variability will have various impacts on socio-economic activities. These impacts may increase as socio-economic activities expand and diversify. The

[22] *Strategy for the Enhancement of National Hydrological Services (NHSs) in Regional Association II (Asia) [2006-2008]*, WMO, August 2005

[23] National implementation of the proposed actions will depend in each case on the level of development or a specific requirement of the corresponding Services.

most obvious potential impacts on hydrology and water resources are potential changes in the frequency and severity of hydrological extremes, long-term changes of hydrological regimes and changes in water resources availability over time and space.

86. A number of studies undertaken in relation to the Intergovernmental Panel on Climate Change (IPCC) [24] indicate potential future increases in flood peaks of approximately 15% in temperate zones due to increased storm activity and overall increases in depth of precipitation.

87. Advances in seasonal prediction provide valuable tools for disaster reduction and mitigation opportunities. Knowledge of the behaviour of the El Niño Southern Oscillation (ENSO) that can profoundly change the weather patterns in Central and South America and influences the number of hurricanes that can be expected in a given season is now essential to the operations on NMHSs and weather/climate impacted activities... Long-range climate prediction of above or below normal storm activity during El Niño and La Niña events can assist with impact adaptation opportunities (e.g. the regulation of reservoirs that can reduce the magnitude of peak storm runoff[25]).

88. Coastal communities must also deal with the implications of sea-level rise, tsunamis, and ocean storm surges in preparing for flooding events. Sea-level rise due to climate change will result in higher tide levels in reaches where the river enters the ocean, thereby reducing the capacity of the channel to carry flood flows, increasing the risk of floods in coastal cities.

Box 12 –Actions [26] ***recommended for addressing climate variability and change in the light of extreme events***

a) Initiate or continue studies on basin, national and regional levels examining the hydrological effect of climate variability and change on flood frequency and magnitude so as to be able to adapt the flood forecasting and warning systems as required.

b) Review new developments in climate indices/signals (e.g. ENSO) for use in hydrological studies and water management.

c) Plan and undertake studies to examine the effects of La Niña and ENSO events on the respective affected regions as a whole and its individual countries.

d) Undertake studies on the use of climate prediction for assessing changes in the availability of fresh-water resources.

5.2.3 Demonstrating the value of meteorological and hydrological data, information and products

89. The societal needs for forecasting and warning information will determine the financial support to the organizations responsible for warnings and disaster prevention. Therefore, continued national awareness of, and demonstration of the benefit of, flood forecasting services are an underlying principle and constitute an opportunity to ensure national support for such services. It is a fact that limitation of financial resources is a major obstacle facing countries with weak flood forecasting systems. This is partly because the value of meteorological and hydrological data, information and products is still not adequately recognized in many countries.

[24] IPCC (1995) *Climate Change 1995, Impacts, Adaptations, Mitigation of Climate Change: Scientific-Technical Analyses*. Cambridge University Press.

[25] *Guidelines for Reducing Flood Losses.* A contribution to the International Strategy for Disaster Reduction, UNDESA, UNISDR, UNESCAP, USA NOAA and WMO

[26] National implementation of the proposed actions will depend in each case on the level of development or a specific requirement of the corresponding Services.

Such recognition would help decision makers in having a more proactive attitude with respect to flood forecasting systems, rather than reacting to a catastrophe when it happens before supporting their implementation.

90. There were not many recommendations on this issue from the workshops. However, in view of its importance the Synthesis Conference agreed to the following recommendations.

Box 13 –Actions [27] ***recommended for demonstrating the value of meteorological and hydrological data, information and products***

a) Develop and implement a programme to raise general awareness of the social and economic importance of flood forecasting of NMHS in order to ensure the required financial, technical and staffing support for these services.

b) Compile documentation on the effects of flooding to help demonstrate to decision-makers the benefits of a flood forecasting system.

c) Governments should, where required, increase support to the NMHSs to enable them to provide appropriate and timely flood forecasting to their nations and fulfil their national, regional and international obligations.

d) NMHSs should take advantage of the World Meteorological Day and the World Water Day celebrations to promote and disseminate information on the role and value of NMHSs.

6. Implementation of the Strategic Action Plan

6.1 Steps proposed for implementation

91. The recommendations contained in ***Chapter 5*** of this Strategic Action Plan originated from the regional workshops and in many cases were repeated in more than one workshop with slight variations. In other words, with the exception of particular regional situations, experts worldwide are in agreement on what needs to be done to improve flood forecasting. Therefore, the obvious question is: Why isn't it being done? What elements are lacking? Is it funding, human resources, political will, institutional frameworks, or a combination of all these elements? And, most important, what can be done differently from now on in order to have the majority of WMO Member countries implement flood forecasting systems according to internationally agreed concepts?

92. The following steps provide guidance on processes that could be envisaged to implement the actions/recommendations contained in the previous section of this document. They are not exclusive and WMO Members are invited to treat this section as a living document and propose new ideas, actions and processes as they evolve:

a) Development of a long term programme for NMHSs, which would take into account their national flood forecasting and warning objectives, their capabilities, and their needs in accordance with their respective national development and priorities, for either national or

[27] National implementation of the proposed actions will depend in each case on the level of development or a specific requirement of the corresponding Services.

joint (with a group of countries of the corresponding WMO Region) implementation through mutual cooperation.

b) Formulation of detailed action plans for each organization and commencement and monitoring of activities, so as to ensure a successful implementation of the planned programme (see ***Section 6.2***).

c) Preparation of a framework under which development assistance would be provided to, and coordinated amongst Members in WMO Regions and various contributing agencies.

d) Identification and sharing of relevant national and international experiences with the purpose of accelerating the implementation, as required, of national and regional plans for the strengthening of flood forecasting and warning related activities.

e) Preparation and initiation of selected demonstration projects in areas of mutual interest.

f) Promotion of the development of regional joint projects in the field of flood forecasting and warning in one or more WMO Regions or economic groups, and to link these with other projects under formulation and/or consideration by Members in the corresponding Regions.

g) Mobilization for funds through national mechanisms, as well as regional and international efforts under the WMO framework.

6.2 Formulation of Implementation Plans

93. The formulation of detailed action plans for each organization and the undertaking of activities from the proposed Strategic Action Plan would comprise and address the key requirements identified during the regional workshops, given in ***Box 2*** above. The matrix in ***Annex 3*** shows the main (tentative) subject areas for which action plans are proposed to be formulated in accordance with flood forecasting and warning capabilities, and which would cover, in a logical sequence, the main components of the flood forecasting chain. These action plans comprise various levels, addressing from very basic requirements, through those of an intermediate level, to those of high sophistication or advanced technical development. In this context, an attempt has also been made to identify the actions that would need to be undertaken on a short, medium and long-term basis. It is logical that for the development of the implementation plans due account will need to be taken of the fact that national flood forecasting and warning activities have significant differences as regards their levels of performance and outputs[28]. Thus, the plans will logically vary and have to be adapted in accordance with current national/regional flood forecasting capabilities, specific requirements and priorities of the corresponding NMHSs.

6.3 Proposed Demonstration Projects

94. It is expected that projects of various types would be planned and implemented under the proposed Strategic Action Plan, namely:

[28] As described in ***Section 2*** of ***Part A*** above:
Level I - Flood Forecasting and Warning services are limited or not operational, and a significant upgrading and strengthening of the basic data collection and transmission networks is required
Level II - Basic infrastructures for Flood Forecasting and Warning services are in place, but which still require upgrading data management procedures and improved methodologies and models for flood forecasting
Level III - Well established Flood Forecasting and Warning services with high quality products and opportunities for further improvement through the use of new technologies

(i) *country-specific projects*, which are those required by a particular country to address a problem given its circumstances;

(ii) *sub-regional projects,* addressing problems that are common to a number of countries with similar geographical (island countries being an example) and climate conditions or a river basin (countries with tropical humid, semi-arid and arid conditions,) etc; and

(iii) *regional projects*, which address problems that are common to a whole WMO Region and generally, would apply to all of its Members.

95. Countries pertaining to a certain region or sub-region would need to agree on projects/activities to be undertaken to strengthen collaboration between NMSs and NHSs for improved flood forecasting and warning.

96. In the context of the above, *demonstration projects* are an important means of showcasing the value of the cooperation between NMSs and NHSs. They would serve the purpose of:

(i) solving a problem under real-life circumstances;

(ii) demonstrating new development approaches and techniques, low and high cost options, such as the use of advanced meteorological forecasting and prediction outputs like those obtained from regional centres and organizations (e.g. ECMWF) and the use of QPE, QPF, NWP, and ensemble forecasting or simplistic stage height correlations;

(iii) constituting a useful and cost-effective learning exercise prior to the implementation of large-scale projects; and

(iv) have the possibility of being replicated in other WMO Regions.

97. It is therefore proposed to undertake a limited number of such *demonstration project*s, in areas of mutual interest; those recommended during the regional workshops have been listed below. It is therefore recommended that NMSs and NHSs, *with the assistance of WMO,* consider, plan, develop outlines, initiate and execute, as appropriate, regional projects on:

(i) Standardized communications and operation terminology for meteorologists and hydrologists in flood forecasting and flood risk management (selected terminology) with a view to communicate to users.

(ii) The processing of hydrological relevant NWP information for flood forecasting in accordance to specific regional requirements.

(iii) Common regional Internet websites for meteorology/hydrology information sharing for improvement of flood forecasting.

(iv) Intercomparison of coupled forecasting models currently in use in the various WMO Regions, to help the countries in identifying the most suitable models to serve their requirements.

(v) Joint research activities on flood forecasting systems and models in countries with similar regional characteristics.

(vi) Storm surge forecasting and warning services.

(vii) Improved precipitation field forecasting as a requisite for an effective flood forecasting.

(viii) Utilization of meteorological products from Regional Centres in flood forecasting.

6.4 Cooperation and Technical Assistance

98. The area of flood forecasting is one that in the past has attracted many generous offers from donor institutions. In effect, as observed by several regional workshops, most of the existing flood forecasting and warning systems have been established as a consequence of a flood disaster, frequently through foreign bilateral cooperation grants. While these efforts are worthy of praise, they seldom provide an adequate answer to the problem at hand. To quote one of the statements of these workshops:

"Technical assistance projects on flood forecasting systems which have external funding – which may, or may not, be reimbursed – rarely take into account the very nature of the river basin, the actual capacities of the receiving country or, above all, the sustainability of the project once external support has ended."

"As regards hydrological models, there was a consensus that no single solution applies to all circumstances. Therefore, models must adapt to the characteristics of each river basin; this results in the need to invest more resources and, for projects based on technical/financial assistance, the need to ensure that assistance is flexible and not determined by commercial interests."

99. National Technical Cooperation Agencies would like to have their efforts duly recognized and, if possible, the technology and expertise of their country disseminated through their assistance projects. One possible proposal would be the creation of a Flood Forecasting and Warning International Support Committee (FFWISC), consisting of representatives of donor countries, to which WMO could provide secretariat services. The FFWISC would, periodically, examine all requests of assistance in this field received by its members, and on a technical basis decide which technology is the most appropriate to each case, trying to reach a balance between members and their capabilities and circumstances.

100. This proposal could offer a mechanism to overcome the frequent situation, where a country affected by flooding is offered several flood forecasting and warning systems, in a non-coordinated and often overlapping fashion. Any proposal to break this unproductive circle would constitute significant progress in this area.

101. In addition to the above, the following steps may be envisaged:

a) The Strategic Action Plan, after its consideration and adoption by the *Synthesis Conference* in November 2006 will be reviewed by the WMO Commission for Hydrology, before being submitted to the Fifteenth Congress of the World Meteorological Organization (Cg-XV) in May 2007 for adoption;

b) A draft assistance programme would be developed, subdivided into projects for implementation by WMO and Members, as well as by other regional and international institutions and donor agencies;

c) Innovative solutions would be sought to implement the assistance programme, such as having Members acting as "Guides in Flood Forecasting and Warning" for a Region or Sub-Region; the "Guides in Flood Forecasting and Warning" could be responsible, in conjunction with the WMO Secretariat, to transfer their technology and methods to other members, prepare appropriate training activities, or assist in mobilizing necessary resources;

d) Strategic alliances – preferably with the NMHSs as drivers - would be sought with other groups and organizations within and also outside the WMO Regions, for the planning and implementation of regional flood forecasting and warning activities.

e) The Strategic Action Plan could be provided as a WMO contribution to the International Flood Initiative and used to direct and focus the activities of this important alliance.

7. WMO and other International Programmes involved in Flood Forecasting and Warning

102. WMO has launched a number of programmes and projects in support of NMSs and NHSs, some of which address in particular early warning of disasters, as well as preparedness and prevention strategies. Therefore, to complement national efforts, the overall strategy should include enhancement of the cooperation with regional initiatives and existing projects that can ensure a critical mass in terms of human resources development and facilities, and also help to attract appropriate resources.

103. WMO would continue to assist NMHSs in their development plans through, among other initiatives, collaboration with regional institutions in the various WMO Regions and support for the mobilization of resources for the implementation of regional projects, particularly in those areas requiring regional cooperation.

104. Directly relevant to NMHSs in the context of this Strategic Action Plan are the following WMO Programmes: World Weather Watch, World Climate, Atmospheric Research and Environment, Application of Meteorology, Hydrology and Water Resources, Education and Training, Technical Cooperation, and the Natural Disaster Prevention and Mitigation Programmes.

105. As regards other UN agencies involved in flood forecasting and warning, relevant examples are among others the UN Department of Economic and Social Affairs (UNDESA); the United Nations Development Programme (UNDP); the UN International Strategy for Disaster Reduction (ISDR). It is also worth mentioning the International Flood Initiative of WMO, UNESCO, UNU and IAHS.

8. Concluding Remarks

106. A flood forecasting and warning system consists of a chain of components starting from monitoring through analysis and forecasting to warning and community response and review/evaluation of operations. This chain is only as strong as its weakest link. Achieving positive outcomes through reduced loss of life and property damage remains the primary focus of a flood forecasting system. This calls for the strengthening, as required, of the various components of the whole system. Access to information, reliability of forecasts and public trust are critical issues to be addressed when developing a modern flood forecasting system. Coordination and cooperation between meteorologists and hydrologists is called for, since it constitutes an important corner stone in the development of new, integrated forecasting products with the overall goal to assist an accelerated national socio-economic development.

ANNEX 1 – References

1. WMO Preparatory Expert Meeting on *Improved Meteorological and Hydrological Forecasting for Flood Situations*, Geneva, Switzerland, April 2003
2. WMO Workshop *on Improved Meteorological and Hydrological Forecasting for Floods In Southern Africa (RA I)*, Pretoria, Republic of South Africa, November 2003
3. WMO Expert Meeting on the Development of the CHy Project *"Global / Regional Short-term Hydrological Forecasting System"*, Pretoria, Republic of South Africa, November 2003
4. Valencia Declaration; WMO Ibero-American Seminar on *Information Systems and Hydrometeorological* Forecasting, Valencia, Spain, end of March – beginning of April, 2004
5. WMO Workshop on *Enhanced Flood Forecasting in Europe*, Bratislava, Slovakia, 12-14 December 2005
6. WMO Regional Expert Meeting on *Improved Meteorological and Hydrological Forecasting in Asia (RA II)*, Bangkok, Thailand, December 2005
7. WMO Regional Expert Meeting on *Improved Meteorological and Hydrological Forecasting in West and Central Africa (RA I),* Niamey, Niger, April 2006
8. WMO Flood Forecasting and Warning Workshop in conjunction with the session of the WMO Regional Association V (South-West Pacific) Working Group on Hydrology, Wellington, New Zealand, January 2002
9. *Integrated Flood Management*; World Meteorological Organization and Global Water Partnership; APFM Technical Document No. 1, second edition, edited by the Technical Support Unit, 2004
10. *Overview Situation Paper on Flood Management Practices*; WMO/GWP Associated Programme on Flood Management; Technical Support Unit, 2004
11. IPCC (1995) *Climate Change 1995, Impacts, Adaptations, Mitigation of Climate Change: Scientific-Technical Analyses.* Cambridge University Press
12. *Guidelines for Reducing Flood Losses.* A contribution to the International Strategy for Disaster Reduction, UNDESA, UNISDR, UNESCAP, USA NOAA and WMO
13. Strategy for the Enhancement of National Hydrological Services (NHSs) in Regional Association II (Asia) [2006-2008], WMO, August 2005
14. WMO (1994) *Guide to Hydrological Practices.* WMO No. 168
15. *Zaragoza Declaration;* Expert Meeting on Flood Forecasting in the Mediterranean Basin, Zaragoza, Spain, September 2006

ANNEX 2 - Summary of the National Flood Forecasting and Warning Situation/Capabilities by WMO Regions *(15.12)*

SITUATION / CAPABILITIES / NEEDS	WMO REGIONAL ASSOCIATIONS[29]					% of total no. of countries
	I[30,31,32]	II[33]	III-IV[34]	VI[35,36,37]	TOTAL	
	Number of countries					
Number of countries having reported during the regional workshops	28	8	15	35	86	
Status of national Flood Forecasting and Warning (FF&W) services						
Well established national FF&W services providing high quality products	2	5	4	20	31	36
Existing national FF&W services providing basic/intermediate products	11	1	11	12	35	41
Insufficient or no national FF capability						
▪ Insufficient observational hydrometeorological data	9	2	1	4	16	19
▪ No experience in flood forecasting activities	3			1	4	5
▪ Flood forecasts not provided on an operational basis	3		2		5	6
▪ No formal organization responsible in place	6	1	2	1	10	12
Hydrological forecasts provided by a regional transboundary river basin authority to a number of countries	12		1	1	14	16

[29] No country reports or detailed information available for RA V countries to allow a statistical analysis

[30] West and Central African countries of RA-I: Benin, Burkina Faso, Côte d'Ivoire, The Gambia, Ghana, Guinea, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone and Togo

[31] Southern African countries of RA-I: Botswana, Lesotho, Malawi, Mozambique, Namibia, Republic of South Africa, Swaziland, Tanzania, Zambia and Zimbabwe

[32] Mediterranean basin countries of RA I: Algeria, Egypt, Libya, Maroc and Tunisia

[33] P.R. China, Hong Kong China, France, Japan, Lao PDR, Malaysia, Sri Lanka, Thailand and Vietnam

[34] Argentina, Bolivia, Brasil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala. Mexico, Nicaragua, Paraguay, Perú, Uruguay and Venezuela

[35] A number of RA-VI countries participated in more than one workshop

[36] Albania, Austria, Azerbaïjan, Belarus, Bulgaria, Czech Republic, Denmark, Estonia, Finland, Germany, Hungary, Latvia, Lithuania, Norway, Poland, Romania, Russian Federation, Slovakia, Switzerland, Sweden, Turkey, Ukraine, Republic of Moldova and Georgia

[37] Mediterranean basin countries of RA VI: Bosnia & Herzegovina, Croatia, France, Greece, Israel, Italy, Jordan, The Former Yugoslav Republic of Macedonia, Portugal, Serbia & Montenegro, Slovenia, Spain, Turkey

ANNEX 3 - Matrix with Main (tentative) Subject Areas for which Action Plans are Proposed to be Formulated in Accordance with Flood Forecasting and Warning Capabilities

xxx – Action required, high priority; xx – Action as needed, intermediate priority; x – Action only if needed, low priority;
[S.T.] – Action to be taken in the short-term; [M.T.] – Medium-term action; [L.T.] – Long-term action
N.A. - Not Applicable under current level of FF&W development

MAIN FLOOD FORECASTING SUBJECT AREAS	TYPE OF ACTION	LEVEL OF FF&W PERFORMANCE AND CAPABILITIES		
		I[38]	II[39]	III[40]
1. Upgrading and strengthening of the basic meteorological and hydrological networks for all general purposes.	**[S.T.]**	**xxx**	**xx**	**x**
2. Strengthening of the hydrometeorological observing network (rainfall and river level monitoring systems with automatic telemetric data transmission) and the required telecommunication systems for flood forecasting purposes.	**[M.T.]**	**xxx**	**xx**	**x**
3. Establishment or upgrading of meteorological radar networks, in combination of different information systems (radar and rain gauges).	**[M.T.]**	**xxx**	**xx**	**x**
4. Development of improved terrestrial and satellite-based observing networks, together with advanced data assimilation capabilities and correction algorithms for precipitation estimates.	**[L.T.]**	**N.A.**	**xxx**	**xx**
5. Establishment of national data collection and sharing mechanisms, based on inputs from various observation platforms and networks.	**[S.T.]**	**xxx**	**xx**	**x**
6. Establishment of on-line communication channels and facilities between the NMS and the NHS, such as direct computer links and on-line communication networks.	**[S.T.]**	**xxx**	**xx**	**x**

[38] ***Level I*** - Flood Forecasting and Warning systems are limited or not operational, and a significant upgrading and strengthening of the basic data collection and transmission networks is required
[39] ***Level II*** - Basic infrastructures for Flood Forecasting and Warning systems are in place, but which still require upgrading data management procedures and improved methodologies and models for flood forecasting
[40] ***Level III*** - Well established Flood Forecasting and Warning systems with high quality products and opportunities for further improvement through the use of new technologies

MAIN FLOOD FORECASTING SUBJECT AREAS	TYPE OF ACTION	LEVEL OF FF&W PERFORMANCE AND CAPABILITIES		
		I[38]	II[39]	III[40]
7. Strengthening or upgrading of the application of data management procedures and improved methodologies and models for flood forecasting to better meet the various requirements of the end users.	**[M.T.]**	**xxx**	**xxx**	**xx**
8. Development/improvement of meteorological forecasting models particularly for hydrological forecasting purposes, in particular of QPE and QPF.	**[M.T.]**	**N.A.**	**xxx**	**xxx**
9. Development of meteorological ensembles coupled with hydrological ensembles for improving long-range hydrological forecasting and decision-making under uncertainty.	**[L.T.]**	**N.A.**	**xxx**	**xxx**
10. Development/adapting/improvement of hydrological forecasting models supported by capacity building activities including staff training.	**[M.T.]**	**xxx**	**xxx**	**xx**
11. Development of calibration techniques for radar and satellite derived rainfall data.	**[M.T.]**	**N.A.**	**xxx**	**xx**
12. Preparation of long-range hydrological forecasting and prediction products.	**[L.T.]**	**N.A.**	**xxx**	**xx**
13. Identifying needs and undertaking of training and capacity building for staff on:	**[S.T.]**	**xxx**	**xx**	**N.A.**
○ basic meteorology and hydrology,	**[S.T.]**	**xxx**	**xx**	**x**
○ hydrological forecasting and warning purposes;	**[M.T.]**	**xxx**	**xx**	**x**
○ specialized training on modern meteorological and hydrological modeling technologies; and	**[M.T.]**	**xxx**	**xx**	**x**
○ modern tools for monitoring, forecasting and communication				
14. Reviewing and proposing administrative reforms required for improved institutional arrangements for flood forecasting operations and warnings in a national context.	**[S.T.]**	**xxx**	**xx**	**x**