WORLD METEOROLOGICAL ORGANIZATION

WMO FACT-FINDING AND NEEDS-ASSESSMENT MISSION TO PAKISTAN

Islamabad

4-8 November 2010

MISSION REPORT

CONTENTS

GENERAL SUMMARY OF THE MISSION

1. BACKGROUND

1.1 Heavy Monsoon rainfall spells during 28-30 July and 5-9 August 2010 induced exceptional severe flash floods and riverine floods in the north of Pakistan, especially in the Khyber Pakhtunkhwa (KPK) Province and Upper Punjab as well as the Baluchistan and Sindh Provinces. The floods caused severe loss of life and also damaged agriculture and urban properties as well as the general infrastructure, including meteorological and hydrological networks, and caused significant disruption to the socio-economic life throughout Pakistan. The total number of affected people is estimated at 20.2 million; 1,961 people died; and 1.9 million homes were damaged or destroyed [Source UNOCHA, 13 October 2010].

1.2 A condolence letter from Mr Michel Jarraud, Secretary-General of WMO, was sent to Dr Qamar-uz-Zaman Chaudhry, Permanent Representative of Pakistan with WMO on 6 August 2010, offering WMO assistance for the restoration of damaged basic infrastructure and asking for high-priority requirements. The WMO Disaster Risk Reduction (DRR) Division developed the disaster situation reports and collaborated with UN partners and the humanitarian processes. The Hydrology and Water Resources (HWR) Branch facilitated the dissemination of flood maps produced by UNOSAT and worked to meet the requirement of the Lahore Flood Forecasting Division of the Pakistan Meteorological Department (PMD) for flood mapping in Sindh region. The Communication and Public Affairs Office posted a specific web news entitled “unprecedented sequence of extreme weather events” on 11 August 2010, and provided a link to the PMD website from the extreme weather events section of WMO’s homepage. H.E. Dr Ishfaq Ahmad, Advisor on Science and Technology and Minister of State, Planning Commission of Pakistan acknowledged WMO initiatives and remained in constant contact with WMO and PMD with regard to WMO follow-up actions on Pakistan floods.

1.3 On 27 August 2010, WMO Secretary-General established a Secretariat Task Force on Pakistan Floods led by the Director of Development and Regional Activities (DRA) Department and the Chief of DRR Division, Weather and DRR Services (WDS) Department, with participation of staff from the Regional Office for Asia and the South-West Pacific (RAP), the HWR Branch and the Cabinet and External Relations (CER) Department. On 14 September 2010, Mr Jean-Maurice Ripert, UN Secretary-General’s Special Envoy for Assistance to Pakistan visited the WMO Secretariat and met with WMO Secretary-General and the Co-Leads of the WMO Task Force on Pakistan Floods. Mr Ripert strongly recommended working with and through PMD with officials engaged in the Damage and Needs Assessment (DNA) development (i.e., the World Bank (WB), the Asian Development Bank (ADB) and the United Nations Development Programme (UNDP)) and carrying out a WMO mission to Pakistan. The Task Force assisted PMD in developing and revising the proposal for high-priority requirements of PMD. On 28 September 2010, the revised PMD high-priority requirements were submitted to: the Planning Commission; the Ministry of Water and Power; the Federal Flood Commission (FFC); the National Disaster Management Authority (NDMA); the UNESCO Islamabad-Office; DNA focal Points in ADB and WB; UNESCAP; and WMO. A WMO ad hoc liaison office was established at PMD premises from 14 October 2010 to 13 November 2010, by relocating the WMO Office for West Asia in Bahrain, with Dr Jaser Rabadi (WMO Representative for West Asia), to support relevant PMD activities.

1.4 UNESCAP organized a Preparatory Meeting for the “High-level Expert Group Meeting towards Developing a Roadmap to reduce Flood Disaster Risks in Pakistan” on 16 September 2010 in Nanjing, China. Dr Tokiyoshi Toya, Director, RAP Office, participated in the Meeting and met with Dr Chaudhry to review the status of PMD, discuss the assistance requirements and plan a WMO mission to Pakistan. Dr Chaudhry, in view of the recent WMO support to PMD after the 2004 Tsunami and the 2005 earthquake, requested a WMO-led fact-finding and needs-assessment mission to Pakistan. He suggested a small mission team composed of about five or six experts, e.g., two from the WMO Secretariat and one/two from Members. UNESCAP has agreed to join this mission with one-two DRR and/or hydrological experts. UNESCO's participation was also explored.

1.5 WMO held a meeting with UNESCO on Pakistan flooding and development of flood forecasting and early warning systems on 25 October 2010 at the WMO Secretariat in Geneva to coordinate WMO and UNESCO activities in Pakistan. The Coordination Meeting discussed and agreed on the thematic topics for coordination, including: flood forecasting; institutional mapping of PMD stakeholders; integrated flood management/flood risk management; and crosscutting areas. It reviewed the outcome of UNESCO Science Sector Flood Mission carried out from 23 to 26 August 2010 and agreed to develop and exchange complementary Terms of Reference for future WMO/UNESCO missions.

2. ORGANIZATION OF THE MISSION

2.1 At the request of H.E. Mr Kamal Majidulla, Special Assistant to the Prime Minister of Pakistan, a WMO fact-finding and needs-assessment mission to Islamabad was carried out from 4 to 8 November 2010, in collaboration with UNESCAP and in coordination with UNESCO, with the purpose of: (a) to make assessment of the damage to hydrometeorological infrastructure and the needs for priority activities of PMD; and (b) to evaluate and design the implementation plan for the development of effective flood early warning systems. The mission team was composed of representatives and experts in meteorology and hydrology from WMO (Dr T. Toya and Dr W. Grabs); UNESCAP (Dr Le Huu Ti and Dr Y. Ono), Japan (Mr Y. Kojo from the Japan Meteorological Agency), and USA (Dr R. Jubach from the Hydrologic Research Centre), and worked in full collaboration with Dr Q. Chaudhry (Permanent Representative of Pakistan with WMO), Mr Arif Mahmood (Director-General of PMD) and PMD staff and with assistance by Dr J. Rabadi, WMO Representative for West Asia. The list of delegation is given in Appendix I.

2.2 The Programme of the mission, as given in Appendix II, was composed of: (1) coordination/consultation meetings with PMD and stakeholders; (2) visit to operational facilities of PMD; and (3) meetings with the senior officials of the Government of Pakistan, as well as several potential donors located in Islamabad, including UNDP, ADB and the Japan International Cooperation Agency (JICA). The list of persons met during the mission is given in Appendix III.

2.3 The mission assessed the current capability of PMD, specifically, with regard to technical details of Pakistan floods in July-August 2010; damage to the hydrometeorological infrastructure; capability of PMD flood monitoring and warning services; responses by stakeholders; community-level dissemination and public awareness, in order to assist in the development of a proposal for the enhancement of its meteorological and hydrological services to implement effective flood early warning systems.

2.4 The mission assisted PMD in the assessment of immediate, medium-term, and long-term priority requirements and in the development of the proposal for the enhancement of PMD in view of possible assistance mechanisms and implementation plan. The findings and recommendations from the fact-finding mission are given below.

2.5 The key findings and recommendations were reported to the UNESCAP Regional High-level Expert Group Meeting to Reduce Flood Disaster Risk in Pakistan, held in Islamabad from 9 to 10 November, immediately after the WMO mission.

3. FUNCTIONS OF THE PAKISTAN METEOROLOGICAL DEPARTMENT (PMD)

Historical Background

3.1 The Pakistan Meteorological Department (PMD) is an attached department to the Ministry of Defence dealing with meteorology, hydrology and seismology. PMD was established immediately after the independence and creation of Pakistan in 1947, and at that time PMD inherited only 15 meteorological observatories from the Meteorological Service then operating in the region. As a signatory of the WMO Convention in 1950, Pakistan became a Member of WMO

in 1951 with PMD being the national focal organization with WMO. Pakistan also became one of the founding Members of the WMO/ESCAP Panel on Tropical Cyclones (PTC) for the Bay of Bengal and Arabian Sea in 1972 and has been hosting the PTC Secretariat since 2000.

3.2 At its inception in 1947, the primary responsibility of PMD was to provide its services mainly to the aviation sector, however, in later years, PMD expanded its areas of work in various other fields including seismology and hydrology (flood forecasting). With the passage of time and due to the advancement in meteorology and its applications, PMD increasingly responded to the growing national and international challenges in the areas of weather, climate, water and seismology. PMD established Regional Meteorological Centres in the provincial capitals of Pakistan. Over the years, PMD not only strengthened its observational network in Pakistan but also established various specialized centres and units including the Flood Forecasting Division in Lahore for better and improved hydrometeorological services and to effectively contribute to socio-economic development of the country. The weather radars were also installed (and upgraded) on seven sites by PMD with the assistance of international donors and WMO (*see paragraph 3.12*). During the era of 2000s, PMD established the following centres:

- National Drought Monitoring and Early Warning Centre, Islamabad;
- National Seismic Monitoring and Tsunami Warning Centre (NSMC), Karachi;
- Marine Meteorology-Tropical Cyclone Warning Centre (TCWC), Karachi;
- Urban Flood Management: Flood Forecasting and Warning System for Islamabad and Rawalpindi; and
- Research and Development Division, Islamabad.

3.3 In early 2007, PMD implemented a numerical weather prediction (NWP) modelling (*see paragraphs 3.22-3.23*). PMD, with the financial support by the government of Pakistan, has been extending its training facilities to the NMHSs staff of neighbouring countries through the WMO Voluntary Cooperation Programme (VCP) since 2008 for a six-month training course every year.

PMD Mission, Objectives and Services

3.4 The mission of PMD is to provide meteorological, hydrological and geophysical expertise and professional services in support of national economic development, and for the safety and benefit of the community; and to provide information on meteorological and geophysical matters with the objective of traffic safety in air, on land and sea, mitigation of disasters due to weather and geophysical phenomena, agriculture development based on climatic potential of the country, prediction and modification of weather forecast. In parallel to the national interest, and consistent with its assigned role from WMO, PMD services aim to deliver quality forecast, warning and advisory services to the North Arabian Sea and territories falling within the area of responsibility.

3.5 The main objectives of PMD are: to monitor the local and regional weather regularly; and to warn the community/stakeholders about “severe weather” which has the potential to disrupt the public life.

3.6 PMD accomplishes the following services:

(1) Observations, data generation and dissemination services in the following areas: (a) surface weather data; (b) upper-air data; (c) earthquake data; (d) astronomical data; (e) solar radiation data; (f) atmosphere Ozone data; (g) Earth's magnetic field data; and (h) background air pollution data;

(2) Aeronautical forecasts and warning services for Civil Aviation, Pakistan Air Force (PAF), Army, Navy and other users;

(3) Flood forecasting and warning services;

(4) Earthquake data and seismic information services to civil engineers and other users for dams, bridges, townships, etc.;

(5) Farmer's weather bulletin and warning services;

(6) Public utility and advisory services in various fields of: (a) planning and development; (b) town planning; (c) construction of roads, bridges, aerodromes, power plants, air-conditioning, etc.; and (d) provision of meteorological/geophysical data for court cases, insurance claim, inquiry reports, district gazetteers, etc.;

(7) Military operation services: (a) weather monitoring at air bases; (b) forecasts and warning for air bases; (c) weather forecasts and monitoring in assigned areas; and (d) Meteor reports;

(8) Marine meteorological forecasting and warning services;

(9) Air pollution monitoring services;

(10) Research activities in the fields of: (a) meteorology; (b) climatology; (c) hydrology; (d) oceanography; (e) atmospheric physics; (f) environmental pollution; (g) geophysics; and (h) agricultural meteorology;

(11) Astronomical services in the fields of: (a) sun rise/set timings; Namaz timings and Qibla direction calculations; (c) morning/evening twilight timings; (d) Sun/Moon eclipse; and (e) Sighting of new moon; and

(12) Training in meteorology and geophysics for: (a) departmental trainees; (b) trainees from other organizations; (c) foreign training; and (d) PAF (Meteorology Branch) trainees.

PMD Organizational Structure and Staffing

3.7 The staff of PMD comprises about 2,500 officers (meteorologists, hydrologists and supporting staff) for meteorological and hydrological services. Out of a total of 2,500 staff members, 98% are male staff. PMD is composed of the following Divisions/Centres: Research and Development Division (Islamabad); National Weather Forecasting Centre (Islamabad); National Drought Monitoring and Early Warning Centre (Islamabad), National Seismic Monitoring and Tsunami Warning Centre (Karachi with backup centre in Islamabad); Flood Forecasting Division (Lahore); Climate Data Processing Centre (Karachi); Marine Meteorology-Tropical Cyclone Warning Centre (Karachi); National Agromet Centre (Islamabad); Institute of Meteorology and Geophysics (Karachi); and four Regional Meteorological Centres (Lahore, Karachi, Peshawar and Quetta). The organizational charts of PMD and its Flood Forecasting Division (Lahore) are shown in Appendix IV.

PMD Budget

3.8 The PMD annual budget (2010-2011) is about 780 million Pakistan Rupees (Rs.) (around USD 9.1 million). The PMD annual budget for the past nine years since 2001-2002 is given in Appendix V.

PMD Forecasting and Warning Services

3.9 In the recent years, PMD has modernized and strengthened its forecasting and warning services which include: (a) automation of surface observing systems and real-time data acquisition; (b) radars and radiosonde systems for weather monitoring; (c) automation of weather data analysis; (d) weather and precipitation monitoring using the earth satellites; and (e) numerical weather prediction (NWP) facilities. In addition, various specialized units and warning centres

have also been established (*see also paragraphs 3.1-3.3*). The establishment of the National Drought Monitoring and Early Warning Centre in Islamabad (with four Regional Centres in all four provinces) was completed in 2005. The real-time early warning system for flash flood was completed in March 2008 with the support of JICA for the Lai Nullah Basin area, extending to the twin cities of Islamabad and Rawalpindi. However, it covers only a small fraction of flash flood-prone areas in Pakistan. Following the disastrous Indian Ocean tsunami in December 2004 and Kashmir Earthquake in October 2005, PMD upgraded and strengthened its seismic monitoring network and established a state-of-the-art Seismic Monitoring and Tsunami Warning System in Pakistan.

3.10 PMD issues pertinent information on river conditions to local, provincial and federal decision-makers and to the general public. The Flood Forecasting Division (FFD) Lahore is a specialized unit of PMD for hydrometeorological services and flood forecasting, with responsibilities for: (a) flood forecasting; (b) river stream flow forecasting; (c) water availability forecast for dams; and (d) assisting water management at dams especially during Monsoon. FFD provides qualitative forecast minimum 24-36 hours in advance of actual precipitation indicating the intensity of rain bearing system (Bulletin A: on a daily basis), and provides quantitative forecast (Bulletin B) about 12-hours advance of actual peak describing range of peak and minimum and maximum volume of flood hydrograph (significant flood forecast/warning) when it is required.

3.11 The flood forecasting system in PMD is supported by: weather radar network; satellite imagery; real-time hydrometeorological data; real-time and prognostic weather charts; numerical weather prediction models; hydrological models; and statistical models. The process of the preparation and dissemination of flood forecast is shown in Appendix VI.

Weather Radar

3.12 The intense rainfall observation in the whole area of Pakistan excluding part of Balochistan, Sindh, KPK, G.B and Federally Administered Tribal Areas (FATA) has been operated by PMD utilizing the seven meteorological radars located in Islamabad and Karachi (installed in 1990 and upgraded in 1998), Dera Ismail (D.I.) Khan and Rahim Yar Khan (installed in 1998) established under the Japanese Grand Aid (JICA projects); and Sialkot (installed in 1978 and upgraded in 2006), Lahore (installed in 1997 and upgraded in 2003) and Mangla (installed in 2008) established under an ADB loan package.

3.13 PMD generally operates the radars continuously only in Monsoon season, in order to save the consumables such as magnetron and the cost of electricity. The Islamabad and Karachi radars have already been operated for more than 19 years, and the D.I. Khan and Rahim Yar Khan radars have been operated for more than 11 years. In this respect, these radars have frequent troubles due to their aging. In particular, it is anticipated that the Islamabad and Karachi radars would not function in near future due to such aging issues.

3.14 All the raw radar data is not collected at the PMD Head Office for cost reasons. The PMD Head Office in Islamabad and other Offices share all the radar image pictures on the PMD webpage uploaded by each radar station through the Internet. The resolution of these radar images is very low and radar data is not calibrated.

Surface observations

3.15 There are around 90 man-operated meteorological observation stations in whole Pakistan. The meteorological observation data collected manually at these stations is transmitted hourly or three hourly through several communication methods, such as analogue radio, land phone, cellular phone, Short Message Service (SMS), Internet and Very Small Aperture Terminal (VSAT).

3.16 The National Drought Monitoring and Early Warning Centre and the Tropical Cyclone Monitoring Centre manage around 50 Automatic Weather Stations (AWSs). The AWS data is

transmitted from each Meteorological Observatory to the PMD Head Office through the Internet, VSAT or General Packet Radio System (GPRS) communication system. All the meteorological observation data is uploaded on the PMD webpage and disclosed to the public. In the near future, the transmission method will be transferred from VSAT to GPRS gradually.

Rainfall observations

3.17 The Water and Power Development Authority (WAPDA) carries out the rainfall observations at 45 stations for the operation of dams. These rainfall stations were installed during 1993 to 2006, and include 15 stations in the Indus River Basin, 15 in the Jhelum River Basin, eight in the Chenab River Basin, six in the Ravi River Basin and one in the Sutlej River Basin. The data from these stations is transmitted through telemetric network to the Flood Forecasting Division Lahore on a daily basis. In addition, PMD has 500 ordinary rainfall gauging stations. The observational data of these stations is collected monthly by different government functionaries of various organizations and sent to PMD by mail, telephone and/or fax.

3.18 The Lai Nullah Flood Forecasting System managed by the Flood Forecasting and Warning Master Control Centre for Lai Nullah (FFWMCC) of PMD at Islamabad has real-time rainfall gauging stations at six designated locations. The rainfall data is transmitted to FFWMCC at PMD Islamabad Head Office through a dedicated radio system in real time.

River water-level observations

3.19 The hourly water-level observation system has functioned at 35 stations out of 45 stations managed by WAPDA, including 11 stations in Indus River, 12 stations in Jhelum River, six stations in Chenab River, five stations in Ravi and one station in Sutlej Rivers. In the Lai Nullah Flood Forecasting System established under a Japan Grant Aid project, two real-time river water-level stations are in operation.

3.20 The above-mentioned hourly water-level observation system managed by WAPDA was established together with rainfall observation system. These hourly water levels have been observed and transmitted to WAPDA and FFD Lahore of PMD through Meteor-Burst-Communication (MBC) system together with rainfall observation data.

Upper-air observations

3.21 There are eight upper-air observation stations in Pakistan. Due to non-availability of spares, only one station (Karachi) is partially operational. At Karachi station, the radiosonde observation is taken once daily at 0000 UTC. PMD has recently procured one SODAR (Sonic Detection and Ranging) model (PA 5.0) that can scan atmosphere up to 5 km. The system has been operational at PMD's Meteorological Complex in Karachi since the last six months. It is difficult to make the other upper-air observation stations functional due to high-cost of consumables, although WMO recommended the radiosonde observations twice a day (at 0000 UTC and 1200 UTC). There are no upper-air observation stations in northern mountainous area.

Numerical Weather Prediction (NWP) facilities

3.22 PMD has been using the High-resolution Regional Model (HRM) of DWD (Deutscher Wetterdienst: National Meteorological Service of Germany) as an operational model for numerical weather prediction (NWP) since January 2007. The model is run with 22 km resolution on high-performance computing cluster with computational power of 215 G-FLOPS and the simulations are performed twice a day by using GME data of 0000 UTC and 1200 UTC. The model outputs (prognostic charts) are uploaded daily at PMD's website: www.pakmet.com.pk.

3.23 In 2009, PMD procured additional servers/hardware with processing power of 1.7 T-FLOPS to upgrade its existing computer system and run the model with the resolution of 7 km. However,

the upgradating of HRM at 7 km resolution was not successful for Pakistan because of the complex topography. The HRM is a hydrostatic model that is limited in representing the full spectra of waves (e.g., trapped lee waves), which are connected to steep slopes. Therefore, after upgradating of hardware, the model with 11 km resolution has been operational since September 2010. Owing to the complex topography, PMD needs non-hydrostatic model for higher resolution. Further, capacity building in high-performance cluster/grid computing and expertise in data assimilation is needed to enhance NWP capabilities and improving NWP products.

3.24 For flood forecasting, the Flood Early Warning System (FEWS) Model (developed by Delft Hydraulic, Netherlands with assistance by National Engineering Services Pakistan (Pvt.) Limited) has been used by FFD Lahore since 2007. The FEWS Model consists of: (a) SAMO module: rainfall runoff model; and (b) SOBEK module: routing model. However, no further improvement has been made in the model since then. There are certain discrepancies in the FEWS Model, i.e., rainfall runoff and routing models for Tarbela upstream and Kabul River have not been developed and incorporated in the FEWS Model. Therefore, FEWS Model does not generate forecast of upstream Tarbela and for Kabul River. The catchments of FEWS Model also do not tally with the radar's catchments. Further, the tributaries which have been incorporated in the FEWS Model are required to be gauged with respect to level/discharge as well as rainfall. For better performance and up-to-the-mark results, the FEWS Model needs to be improved or replaced with some more reliable and sophisticated hydrological or flood forecasting model.

PMD DRR Capacities

3.25 Pakistan has a National Disaster Response Plan which covers the Standard Operating Procedures (SOP), roles and responsibilities of stakeholders and actions required at national to local levels. PMD is the focal agency to issue forecasts and warnings on natural hazards that may cause disasters to all national, regional and local agencies, and the National Disaster Management Authority (NDMA) advises agencies for response at national to local levels. PMD provides subsequent monitoring and forecasting services to support response and recovery activities. Efforts are being made to implement a multi-hazard early warning system through engaging all stakeholders and international organizations for effective early warning and response system. PMD has quality-controlled historical databases of hazards; statistical analyses to characterize the hazards; analyses of the potential impacts; and hazard mapping and high-risk zone analysis.

3.26 During the mission, two questionnaires were completed by the Pakistan Meteorological Department (PMD): "Tool for Assessment of Institutional Capacities in Early Warning Systems" (*Reference I*); and "Tool for the Assessment of Capacities of National Meteorological and Hydrological Services" (*Reference II*) that assessed the technical capacities, gaps and needs of the Department as well as national capacities in Early Warning Systems. The survey results indicated that the while PMD has significant capacities in observing, forecasting of their primary hydrometeorological hazards (e.g., flooding, tropical cyclones, severe storms, heat and cold waves, etc.) there remain significant challenges such as the need for:

- Increasing the spatial coverage of automatic weather stations especially for the more remote areas of the country as well as additional resources (e.g., spare parts, professional staff, financial resources) for the maintenance of these stations;
- Professional training and capacity building for PMD personnel in latest technologies and methods in meteorology, numerical weather prediction, hydrology, hydrological modelling climatology, climate change and data assimilation;
- Improved coordination mechanisms with early warning system stakeholders (e.g., disaster management authorities) including watch and warning coordination and exchange of hydrometeorological data and information (e.g., analysis, forecasts, bulletins);
- Improved public education and training on the impacts of hazards and understanding what to do in the event of the issuance of watches and warnings; and
- Improved dissemination tools and mechanisms for transmission of multi-hazard information (e.g., forecasts, advisories, watches and warnings).

4. KEY FINDINGS

4.1 Review of Severe Flooding Situation

Analysis of Weather Situation

4.1.1 In Pakistan, Monsoon season normally starts in July and continues to the end of September. During the Monsoon season, in most cases, the low-pressure area develops in the Bay of Bengal and moves towards Pakistan along the periphery of Tibetan Sub-Tropical High. Sometimes, the low-pressure area also develops in the North Arabian Sea and moves towards Pakistan. However, the Bay of Bengal is more active than the North Arabian Sea with respect to cyclogenesis. In addition, the low-pressure area also develops in the north of Pakistan due to the frontal weather systems that move along the westerly waves over mid-latitudes from west to east during the Monsoon season. According to the climate statistics for the period 1960-2009, the interaction of Westerly and Easterly Weather Systems may occur over the north-eastern part of Pakistan with heavy rainfall during the Monsoon season. The duration of such interaction is normally 8 to 12 hours.

4.1.2 The mission recognized that, in July 2010, the Arabian Sub-Tropical High and Tibetan Sub-Tropical High shifted to north, thus Monsoon Weather System which developed on 24 July in the Bay of Bengal penetrated westward reaching Pakistan on 27 July. This Monsoon Weather System merged with the seasonal low (already present over Pakistan) and interacted with the westerly wave over north-western part of Pakistan (instead of north-eastern part). The westerly wave was associated with a jet stream of strong wind of more than 100 knots at 200 hPa. This interaction of two weather systems helped transport the moisture even above 500 hPa levels from the North Arabian Sea and created a thick layer of moist air above the mid-troposphere level over the catchments of Kabul and Indus Rivers. The northward shift of Tibetan Sub-Tropical High acted as a blocking high and caused the interaction to prolong for 36-48 hours and produced extreme rainfall over north-western Pakistan from 28 to 30 July. During this rainfall spell, the total rainfall in the northwest Pakistan amounted to more than 300 mm. From 5 to 9 August 2010, there was another rainfall spell, again due to interaction of westerly wave and monsoon weather system of a lesser intensity. This interaction caused wide spread rains in Pakistan especially heavy rainfall was received in northern and central parts of the country. The total amounts of rainfall recorded in July and August 2010 at some stations are given in Table 1 below.

Table 1 - Total amounts of rainfall observed in July and August 2010

July 2010				***August 2010***			
Station	***Observed***	***Normal***	***%Departure***	***Station***	***Observed***	***Normal***	***%Departure***
Muzaffarabad	579.0	359.4	61.1	Sialkot	416.0	323.5	28.6
Murree	579.0	364.1	59.0	D.I. Khan	376.0	61.7	509.4
Garhi Dupatta	570.0	265.6	114.6	Kamra	364.0	210.3	73.1
Mianwali	528.0*	134.8	291.7	Risalpur	362.0	143.1	153.0
Rawalakot	521.0	322.6	61.5	Dir	292.0	156.0	87.2
Kamra	479.0	175.7	172.6	Saidu Sharif	286.0	125.9	127.2
Saidu Sharif	471.0*	152.6	208.7	Mithi	278.0	80.9	243.6
Risalpur	433.0*	132.4	227.0	Khanpur	277.0	17.5	1482.9

Kotli	417.0	285.8	45.9	Murree	269.0	335.5	-19.8
Peshawar	402.0*	46.1	772.0	Parchinar	260.0	97.4	166.9
Kakul	389.0	263.6	47.6	Islamabad (AP)	245.0	348.1	-29.6
Cherat	388.0*	93.4	315.4	Mangla	241.0	251.6	-4.2
Islamabad (AP)	383.0	305.3	25.5	Kohat	237.0	115.6	105.0
Sialkot	373.0	304.1	22.7	Mandi Bhauddin	231.0	168.2	37.3
Kohat	345.0*	75.3	358.2	Sialkot	416.0	323.5	28.6

* Highest in the record

Technical Details of Floods and its Impacts

4.1.3 According to the various situation reports of the UN Office for Coordination of Humanitarian Affairs (OCHA) and the briefing provided to the mission, heavy rains during the months of July and August had triggered both flash floods and riverine floods in several parts of the country resulting in a loss of life and widespread displacement. The first heavy rainfall spell (28 to 30 July 2010) in the north of Pakistan especially in Khyber Pukhtunkhwa (KPK) province and adjoining upper parts of Punjab province caused firstly severe flash flooding and then history's extreme high riverine flooding in Pakistan. The second rainfall spell (5 to 9 August 2010) generated a second flood wave in the Indus River and its tributaries aggravating the already flooded fields of Punjab, KPK and Sindh. This second flood wave practically merged with the first flood wave below Taunsa barrage (on the Indus River in Punjab) and created havoc in the surrounding areas and downstream Taunsa. Several areas in Khyber Pakhtunkhwa (KPK), Baluchistan, Punjab, and Sindh were worst affected areas. Government's estimates indicate that the floods have affected about 20 million people, of which over 75 percent are in Sindh and Punjab.

4.1.4 The flooding of 2010 can be hydrologically categorized into two major areas: upstream of the Tarbela Dam and downstream of the Tarbela Dam, specifically downstream of the confluence of the Indus River and the Kabul River.

a. Upstream area of Tarbela Dam

4.1.5 For the upstream area of the Tarbela Dam, the flooding could be generally described as flash floods, due to the geographical conditions as well as the lack of hydrological information in time for adequate forecasts and warning. The severe damage in this area could be attributed to the impacts of the flash floods. There were major damages to infrastructure: several thousands of houses had been destroyed and at least 45 bridges all over the KPK Province had been damaged.

Khyber Pakhtunkhwa (KPK)

4.1.6 In KPK, the 2010 floods were the worst floods since 1929 and 25 districts were said to be hit. At least 400,000 people were affected. Swat, Nowshahra, Charsadda, D.I. Khan, Tank and Upper and Lower Dir districts were among the districts badly hit. Some of these areas received between 300 and 400 mm of rain during 36-48 hours, which was the highest ever recorded rainfall in the region.

4.1.7 Reports indicated that in Charsadda, more than 5,000 homes were underwater and 20 villages were affected. The road links to Peshawar were also cut off. In Swat, the Swat River had broken its banks. Four subdivisions were affected, with 2 villages flooded and more than a thousand homes underwater. Hundreds of hotels and shops had also been swept away. In D.I. Khan and Tank initial reports said 23 villages had been affected. The Indus River overflowed. In

Mansehra initial reports suggested some villages had been hit by landslides. The worst affected districts in KPK were Charsadda, Swat, Nowshera, D.I. Khan, Tank, and Lower and Upper Dir.

4.1.8 Water from Kabul River entered many parts of Nowshera district, flooding houses and stranding hundreds of thousands of people in their homes. An important humanitarian hub and warehouse complex in Pirpai was also flooded, making it impossible to move relief items to affected areas. In the Swat District, the Swat River had washed away most of the bridges along with dozens of shops, hotels and private residents. Thousands of civilians had to be evacuated to high grounds north of the District Capital Mingora.

4.1.9 Also, the Districts of Tanks and D.I. Khan were affected, where several hundred mud houses had been destroyed by the rain and floods. The water entered the district capitals and set parts of both cities under water.

4.1.10 New towns and villages were inundated in Sindh's Dadu and Jamshoro districts over the weekend as Manchar Lake overflowed. Floodwaters entered Jhangar and Bajara towns, near the southern bank of the lake, on 13 September. Water supplies to Sehwan tehsil in Jamshoro were reportedly cut on the same day, due to possible contamination.

4.1.11 Thousands of people lost their homes and livelihoods. Crops were destroyed, and roads and bridges were damaged. All seven districts of FATA were also affected, according to the FATA Disaster Management Authority, although the severity was unclear.

4.1.12 Water had slowly started to recede during the second week of August from many flood affected areas of KPK, leaving behind a trail of destruction. The death toll, according to various sources, was more than 1,000 for KPK. According to the Provincial Disaster Management Authority (PDMA), the following seven districts would have the highest need for humanitarian assistance in the immediate term: Nowshera, Charsadda, Swat, Shangla, Kohistan, D.I. Khan and Tank.

4.1.13 A rapid assessment carried out by the UN World Food Programme (WFP) in four districts (Nowshera, Charsadda, Mardan and Peshawar) puts the figure of people who lost their homes or were temporarily displaced at nearly 980,000, and the number of affected people is expected to rise above one million.

b. Downstream area of Tarbela Dam

4.1.14 For the downstream area, the most important impacts were resulted from the combined effects of high floods propagated from upstream area, the poor draining conditions created by changes in topographical and river morphological conditions during the past several decades and also the effects of high tides.

Baluchistan

4.1.15 In Baluchistan, floods hit seven districts including Sibi, Kohlu and Barkhan. It was reported that some 150,000 people were affected.

Punjab

4.1.16 The rains hit parts of upper Punjab; Mianwali, Attock, Rawalpindi and Jhelum in particular. Moreover, moderate to heavy rains continued to batter the flood plains in Rajanpur.

4.1.17 At the end of August, though floodwaters began to recede in many areas, parts of Sindh continued to battle with severe flooding. Reports indicated that the worst flooding at the end of August was in Dadu and Qambar Shahdadkot districts, on the western side of the Indus, and Thatta, where high sea levels were slowing down the entry of the floodwaters into the sea. Low-

lying areas in Badin and Jamshoro districts were also reported to be under water. Floodwaters had entered Sujawal town in Thatta by 29 August according to media reports, and road links from the town to other areas were cut off. While efforts to divert floodwaters from Thatta city appeared to have been successful and some residents were returning to their homes, tens of thousands of families were still seeking shelter in Makli graveyard on the outskirts of Thatta. Others had moved towards Karachi and Hyderabad. There was also continuing migration northwards towards Sukkur.

4.1.18 On 1 September, the Government reported that over 18 million people were affected by the floods. The death toll stood at 1,667. Over 1.2 million houses were damaged or destroyed. Floodwaters were receding in many areas, and though there were concerns about standing water that remained in Punjab and other areas, the worst of the flooding was taking place in Sindh.

4.1.19 Two areas in Sindh were affected by major flooding since 30 August 2010. On Monday, 30 August 2010, floodwaters entered Gaji Khuhwar, a town of 40,000 people in Warah tehsil, Qamber Shahdadkot district. Efforts to divert floodwaters from Warah town were then made. Since 1 September, new flooding was also reported from Mehar and Khairpur Nathan Shah tehsils in neighbouring Dadu district. Dadu and Johi towns were under threat as floodwaters continued to move southwards through Hamal Lake. Flooding in this area had extended west and south from the Indus since an embankment was breached in the middle of August 2010, inundating Jacobabad and parts of Jaffarabad and Nasirabad districts in the neighbouring province of Balochistan.

4.1.20 Further south, in Thatta district, almost 1,300 km^2 of land was reported to have been flooded following a breach near Surjani, displacing more than half a million people. An estimated 400,000 people were believed to have moved to higher ground on the outskirts of Makli, near Thatta town, and along the Karachi-Hyderabad highway. Others moved towards Golarchi in Badin district, to the east of Thatta. Floodwaters were threatening the towns of Jati and Chohar Jamali, near the coast to the east of the Indus. Parts of the highway between Thatta and Badin had been submerged.

4.1.21 The flood impact profiles of Pakistan and Khyber Pakhtunkhwa (KPK) as well as the flood analysis based on time series of satellite data recorded from 28 July to 16 September 2010 are given in Appendix VII.

4.2 Services provided by PMD during Floods

Weather and Flood Forecasting

4.2.1 The mission recognized that PMD's forecasts at different stages of the floods were reasonably accurate and timely. PMD issued the Monsoon Seasonal Outlook for July-September 2010 on 24 June 2010, which contains the warning about possible floods in the following message: "Due to the interaction of westerly-easterly waves, few very heavy rainfall events would also occur over north Pakistan that may cause urban/flash flooding during July-September". On 20 July 2010, PMD informed the public through media of the formation of Monsoon weather system and its likely movement towards Pakistan. The weather forecasts, advisories and warnings issued on 20, 24, 27, 28 and 29 July 2010 indicated a greater threat of flash floods and riverine floods in Khyber Pakhtunkhwa (KPK) and other parts of the country. The rainfall in KPK started during the night of 28 July 2010, then heavy rainfall occurred during the night of 29 July 2010. On average, 400 mm of rainfall occurred in two days out of which about 250 mm rainfalls on the night of 29 July in KPK that caused flash flood/riverine floods.

4.2.2 PMD also well predicted the second Monsoon rainfall spell starting from 2 August 2010, with indication of the third spell from 6 to 9 August 2010. The warning advisory was issued on 31 July 2010 predicting that another Monsoon System would cause heavy rainfall during the first week of August 2010. Then advisories about the second rainfall spell were updated on a daily basis.

4.2.3 Significant flood forecasts for Indus River were disseminated by fax/phone/SMS and via web service and with electronic and print media to: Federal Minister for Water and Power; Chairman of NDMA; Secretaries of Ministries of Defence, Water and Power, and Information; and Indus River System Authority and National Power Construction Corporation (NPCC)/WAPDA, as well as TV and radio media, the Secretary General of the Pakistan Red Crescent Society and regional authorities.

4.2.4 The mission recognized that the forecasting services of PMD significantly contributed to reduction of loss of lives and property that otherwise could be expected from a flood disaster of that magnitude.

Damage to PMD Observing Infrastructure

4.2.5 Some hydrometeorological facilities of PMD were damaged totally or partially by flash floods and riverine floods. Ten Automatic Weather Stations (AWSs) at the following sites were damaged: Dir, Saidu Sharif and Chitral (in KPK Province); Bahawalnagar and Dera Ghazi Khan (in Punjab Province); Turbat and Uthal (in Balochistan Province); Dadu and Badin (in Sindh Province); and Chillas (in Gilgit Baltistan Province).

4.2.6 Ten meteorological stations located in the flood-affected areas were severely damaged: Malam Jabba, Kalam and Timargra stations (in KPK Province); Dera Ghazi Khan, Bahawalpur and Jhang stations (in Punjab Province); Jacobabad, Lasbellah and Sibi stations (in Balochistan Province); and Chillas station (in Gilgit Baltistan Province).

4.2.7 Three stations out of 45 rainfall stations were submerged and damaged and malfunctioned although all the stations had been operated until 31July 2010. Among the three stations, two stations have water-level observation function and therefore the operations have malfunctioned since 1 August 2010.

4.2.8 Loss of the above observing infrastructure has severely limited the forecasting capabilities of PMD. The urgent restoration or replacement of the damaged AWSs and surface observing stations is required for the preparation for the possible future floods during the 2011 Monsoon season.

Damage to WAPDA river gauging stations

4.2.9 WAPDA manages two systems for measuring flow of rivers, namely: the Telemetry System and the Manual Gauging Measuring System. The Telemetry Stations at Attock/Khairabad (Indus River), Nowshera (Kabul River) and downstream Warsak Dam (Kabul River) were completely damaged and the Telemetry Stations at Chakdara (Swat River) and Chattar Calas (Jhelum River) were partially damaged during the extremely high floods. The total estimated cost of damaged Telemetry Stations was reported to be Rs. 13.6 million (about USD 160,000), while the total loss of telecommunication equipment (wireless sets, charges, generators, etc. lost or damaged) has been estimated to be Rs. 35.2 million (about USD 411,000) by WAPDA (*Reference III*). One Station at Chakdara (Swat River) was rehabilitated using spares available in stock and reported to be working satisfactorily. The remaining four stations could not be rehabilitated due to non-availability of spares in stock of WAPDA. In addition, some 20 Hydrometeorological Stations of Surface Water Hydrology Project (Manual Gauging Measuring System) were also damaged completely or partially. The damage to these stations was estimated to be Rs. 20.0 million (about USD 233,000) by WAPDA (*Reference IV*). Although all these stations have temporarily been restored by WAPDA and necessary data is being collected except for discharge at a few stations, sufficient funds are needed to restore the stations permanently before the start of the 2011 Monsoon season.

4.3 Response by the Different Partners and Stakeholders

4.3.1 Consultations with various key stakeholders, including senior government officials (*see Appendix III*) provided a comprehensive spectrum of views on the experiences of the floods; the services provided in terms of flood forecasting for effective disaster risk management; responses to the proposal of PMD to improve flood forecasting services; and their respective visions for the future.

a. Views of stakeholders on experiences of the 2010 floods

4.3.2 All stakeholders recognized the 2010 floods as exceptional but similar in magnitude to past floods with 1994 being mentioned specifically. However, what did appear to be different for the 2010 floods as compared to past flooding events was the increased population and subsequent increase in population densities as well as a large increase in infrastructure vulnerable to floods including roads, railways, settlings, industries in the floodplains coupled with a lack of institutional capacity to handle such a large event. They indicated that the lack of adequate preparedness procedures, especially in terms of recent experiences (at least during the past eight decades), made the country much more vulnerable.

4.3.3 Many stakeholders attributed the severe impacts of flash floods upstream of the Tarbela Dam and the coincidence of the flood peaks from the Indus and Kabul Rivers to the lack of hydro-meteorological and hydrological data. They recognized the importance of acquiring timely and accurate data on rainfall and stream flows in the upper catchments as well as within the various small catchments with steep slopes. They recommended extra efforts be made to introduce flash flood forecasting and warning.

4.3.4 Many stakeholders attributed the lack of effective early warnings to the lack of updated information on many flood plains and waterways which are obstructed by land-use practices in recent years as well as by the aggradation of river beds and changes in the river morphology. They recommended that urgent actions be taken to overcome these challenges as part of the improvement of flood forecasting services.

4.3.5 Several stakeholders highlighted the importance of morphological changes on the calibration of modelling tools as well as flood monitoring, especially in terms of flood flow forecasts for which updated and accurate rating curves are a pre-requisite to calculate discharge from gauge height observations.

b. Views of stakeholders on flood forecasting and warning services

4.3.6 It was found that in general flood forecasts issued by PMD were duly transmitted to the respective Government authorities and departments. All the authorities/organizations participating in the coordination meeting commended the timely issuance of early warning advisories and relevant information on possible floods by PMD.

4.3.7 Most of the stakeholders attributed the relatively small number of deaths by this exceptional flood to the good forecasting services provided by PMD and on-the-ground response to the warnings. Nevertheless, many of these stakeholders considered that the number of deaths as well as damage could have been much reduced, had the services been improved in time to support more effective decision-making on disaster risk management. These stakeholders also recognized several important gaps in the translation of flood forecasts into flood warnings and ultimately DRR actions at most of the levels, especially at the local level.

4.3.8 Several stakeholders expressed their appreciation to PMD for the timely assessment of needs for improvement in the services provided and were well aware of the findings of PMD on the role of the convergence of the two weather systems in the occurrence of the exceptional rainfalls and also the persisting climatic conditions that prolonged the flooding. These stakeholders

recognized the importance of this new knowledge in the improvement of not only flood forecasting services but also in the management of water resources in the country to cope with both floods and drought, especially for operations of major reservoirs including the Tarbela and Mangla Dams.

4.3.9 In relation to the operations of the Tarbela Dam, the mission was informed of a major decision by the dam operator, WAPDA, to allow filling of the reservoir up to 7 feet within a day against the limit of 2 feet stipulated in the Standard Operating Procedures (SOP). This decision was attributed to the confidence in the inflow forecasting (through flood forecasting services of PMD). WAPDA also pointed out possible additional benefits if more accurate long-term forecasts could be provided at the beginning of the flood season. Many stakeholders however recognized the technical difficulties in terms of assuring accuracy in the long-term forecasts and the need in providing decision-support tools to translate uncertainties in long-term forecasts into decision-making options for more effective risk management.

4.3.10 Stakeholders also realized the necessity for an integrated approach to the management of dams and reservoirs in the Indus basin as a possibly effective means to alleviate negative impacts of floods.

c. Views of stakeholders on PMD's proposal to improve forecasting services

4.3.11 For all stakeholders, the 2010 flood was recognized as a critical opportunity to modernize the flood forecasting and warning system of the country to prepare Pakistan to meet new challenges in socio-economic development and climate change. Stakeholders recognized that PMD is the key driver in improved forecasting and certain aspects of flood management activities in close collaboration with mandated partner organizations.

4.3.12 Many stakeholders acknowledged the importance of the strategy proposed by PMD on human resources development (HRD) for decentralization of flood forecasting services for more effective decision-making on flood management. They expressed their support and agreed to participate in the implementation of the strategy, especially in the plan to establish various regional flood forecasting centres. In this regard, several stakeholders called for improvement in the SOP of flood forecasting services and dam/reservoir management taking into account the 2010 flood experiences and the implementation of a flood forecasting and management strategy building on a decentralized approach.

4.3.13 Several stakeholders pointed out the need to link improvement in flood forecasting services to enhanced capacity in decision-making for more effective disaster risk management at all levels. In this connection, they called for improvement in flash flood forecasting and warning, flood flow simulation in flood plains with updated information on flood plain mapping, and in reservoir operations.

d. Views of stakeholders on their visions for flood resilience in the future

4.3.14 Many stakeholders recognized the importance of having a clear and practicable strategy to improve flood resilience of the country through meeting the urgent needs to be fully prepared for the 2011 floods, the need to cope with emerging challenges of socio-economic development and the increase in extreme weather events, and the need to have an holistic flood management within the framework of integrated water resources management.

4.3.15 Stakeholders stated that Pakistan is already a water-stressed country with water management and disaster reduction highly exposed to both natural hydrometeorological phenomena such as drought and floods and man-made changes to the river basin including its transboundary component. Stakeholders reiterated the importance of: (a) addressing flood management in a holistic approach, making all relevant organizations partners to the process; (b) identifying deficiencies and improving on them in a phased manner so as to address immediate (urgent), medium- and long-term needs; and (c) improving the scientific basis to better understand

meteorological and hydrological processes that result in the occurrence of extreme events: not only floods but also drought, heat waves and other hydrometeorological phenomena.

4.3.16 With respect to the urgent needs to be prepared for the 2011 flood season, many stakeholders expressed their support for urgent improvement of key flood forecasting infrastructure at the federal level, provincial level and selected local levels. At the local level, urgent rehabilitation of monitoring and communication facilities as well as key capacity building to translate flood forecasts into community-level action was recommended. At the provincial level, urgent improvement in the operations of the flood forecasting centres was recommended. At the federal level, key facilities and capacity building to deal with flash floods and support DRR decision-making were recommended.

4.3.17 Stakeholders also recognized that the occurrence of floods and droughts need to be seen from a regional perspective, as the entire region is prone to hydrometeorological disasters. Stakeholders felt that this would call for an enhancement of scientific cooperation in the region that would also include promoting the timely exchange of scientific findings, warnings and sharing of relevant hydrological and meteorological data and information for warning purposes. It was stated that ultimately people in all countries of the region would benefit from these arrangements that lead to largely improved delivery of forecasting services.

4.3.18 Stakeholders were of the opinion that in an integrated flood management approach all options need to be reviewed to alleviate the risk of flood disasters while enhancing the beneficial effects of floods. In particular, this would relate to options for the temporary storage of excess flood waters while also seeking options to utilize flood waters for the recharge of groundwater aquifers.

4.3.19 In this regard, stakeholders are concerned about the unabated rate of de-glaciation and storage of precipitation in snow fields in the Himalayas that will result in accelerated spring floods due to snow melt and less storage capacity of water in the form of snowfields and glaciers that will effect agriculture, animal husbandry and hydropower generation in the upper reaches of the Indus and its major tributaries. In addition, climate-induced warming is expected to add on hazards such as debris flows and avalanches as well as the formation of potentially dangerous glacier lakes that are prone to burst.

4.3.20 Especially from the perspective of disaster management and improved understanding of the nature of a potential disaster (floods, drought) including its magnitude, frequency, extent and persistence are essential for planning and decision-making. This would call for a revision of the way in which forecasts are formulated and issued to the respective authorities. In this respect, the promotion of multi-hazard early warnings to extend lead-time for actions is likewise critical.

4.3.21 The stakeholders urged that efforts be made by all parties concerned to translate the needs at the immediate future (10 months), medium term (2-3 years) and long term (beyond 3 years) into actions as part of the integrated programme for rehabilitation, recovery and socio-economic development. They also urged the mission to make its utmost efforts to involve key parties in the implementation of the findings.

4.3.22 All stakeholders recognized the urgency to develop an immediate action plan to make best use of the upcoming 10 months before the start of the next flood season. Stakeholders were unanimously of the opinion that the immediate action plan needs to be sufficiently embedded in a medium- and long-term perspectives for river basin management.

4.3.23 Several stakeholders called for assistance and support to restore various flood forecasting infrastructure facilities, many of which are required before the onset of the 2011 flood season.

4.4 Summary of Findings on Flood Forecasting

4.4.1 The mission recognized that there were two distinctively different processes that caused floods in Pakistan, namely *riverine floods* with relatively slow reaction times of the hydrological system and *flash floods* with short response time of the hydrological system. Flash flood is considered the actual killer of people while riverine flood is mainly causing extensive damage to property, infrastructure and damage of livelihoods. Flash flood is extremely difficult to be forecasted and is mainly a now-casting problem while riverine flood can be forecasted with available hydrological flood models and flood routing methods.

4.4.2 In the case of the 2010 Pakistan floods, it became evident that methods to predict flash floods were largely not in place although weather forecasting information had been available for the northeast and northwest of Pakistan. Regarding riverine floods, insufficient hydrological information had been available for forecasting from major tributaries. In addition, forecasting skills were compromised by insufficient information available from headwaters of transboundary tributaries to the Indus including from Chenab, Sutlej and Jhelum Rivers and the Kabul River system. In the process of the progression of the first and second flood waves, forecasting and flood routing was further impeded by the loss of gauging information due to the malfunction/destruction of river gauges. Breaching of levees also had negative effects on providing more accurate flood forecasting services.

4.4.3 It was recognized that PMD for flood forecasting services relies on hydrological networks that are not under the control of PMD but rather WAPDA and the Irrigation Department. There are open questions related to the quality assurance of these data meeting the high standards required for accurate flood forecasting services and the overall adequacy of the observation network in terms of location and density as well as available and reliable telecommunication facilities to ensure timely relay of critical data to forecasting centres.

4.4.4 The PMD numerical weather prediction (NWP) model (*see paragraphs 3.22-3.23*) did not necessarily provide adequate analyses of the situation. There were noticeable failures in the flood warning and evacuation processes – all aspects of communication need improvement. One example is: there were no warnings for the many and severe flash floods that occurred in the northwest sections of the country. To improve these shortcomings, PMD must become a key agency to move Pakistan forward in successfully dealing with hydrometeorological hazards.

4.4.5 The use of flood forecasting models seems to be not fully adequate in part due to the limited applicability of hydrological models used at present. Although a modelling framework has been established (Flood Early Warning System), there is no recent upgrade of modelling and data management software that is critical to improve the accuracy of flood forecasting services.

4.4.6 An issue that became apparent during the mission was the management of dams and reservoirs. Although these dams and reservoirs had been primarily designed in support of agriculture and hydropower generation, it was felt that they could also play a potentially significant role in flood management.

4.4.7 As a result of the recent floods, river morphology and cross-sections at key flood forecasting sites are highly likely to have changed significantly. As a result, rating curves that had been established are no longer valid. The calculation of discharge as a function of water level observations is however critical to provide quantitative information on river discharge for water flood forecasting and water management, most notably the hydropower and agriculture sectors.

4.4.8 There was an overall consensus that flood forecasting information was not always translated into information at the district and community levels to guide decision-making. There was felt need to relate flood forecasting and likewise meteorological forecasting to impacts and consequences that are linked to frequencies and probabilities of occurrence. Weather and flood

forecasting information was felt to be insufficiently embedded in an overall risk management approach.

4.4.9 It was learned that the "Indus River Authority" had recently been created by Parliament that yet has to develop a composite plan of operation. This was seen as an additional opportunity to develop a basin-wide integrated flood management strategy.

4.4.10 Aside from a change of the morphology of rivers as a result of the extraordinary flood event of 2010, it was also recognized that the sediment load of tributaries into the main stem of the Indus River aggravate the flood hazard in the Indus plains as the river bed is elevated with the consequence that levees and embankments may be overtopped under the current design practices.

4.5 WMO Actions for Assistance for PMD and PMD Actions after the 2010 Floods

4.5.1 Following the 2010 floods, WMO took the following actions related to public affairs in order to make sure that the media, humanitarian agencies and the public know where to find the best possible flood and weather information:

- link from the WMO homepage to the daily updated information from PMD;
- presence of PMD at UN press briefings in the field (in line with UNCG SOP);
- information at UN press briefings in New York and Geneva (drawing attention to the fact that wrong information had created unnecessary panic in one town as mentioned in PMD website);
- by informing the Permanent Mission of Pakistan in Geneva; and
- in interviews.

4.5.2 The WMO Task Force on Pakistan Floods (*see paragraph 1.3*) held its first and second meetings on 13 September and 15 October 2010 with participation of relevant Departments and Offices in the WMO Secretariat. The Task Force reviewed the progress on the ongoing activities related to Pakistan Floods and discussed the planned WMO actions. The WMO Executive Management was kept informed of the progress on WMO actions through Briefing Notes No. 1 (9 September), No. 2 (30 September) and No. 3 (15 October 2010). The communication between WMO and PMD (and the Permanent Mission of Pakistan in Geneva) has been maintained and strengthened through RAP Office (Director, RAP Office), and the coordination with UNESCO and other UN partners was made mainly by Chief, DRR Division.

4.5.3 A WMO ad hoc liaison office was established at PMD premises from 14 October 2010 to 13 November 2010, by relocating the WMO Office for West Asia in Bahrain, with Dr Jaser Rabadi (WMO Representative for West Asia). Dr Rabadi liaised with PMD and maintained regular contact with DRA/RAP Office; coordinated with the UN Resident Coordinator, UN Country Office DRR Coordinator and the UN Country Team in Islamabad in particular with focal points of UNDP and UNESCO involved in recovery and reconstruction of the DRR- and EWS-related matters, as well as Damage and Needs Assessment (DNA) team and followed up on the DNA Report (incorporation of PMD proposal into DNA Report); and provided assistance in the organization of the WMO fact-finding and needs-assessment mission (4-8 November 2010), the UNESCAP Regional High-level Expert Group Meeting to Reduce Flood Disaster Risk in Pakistan (9-10 November 2010), and other UN meetings related to Pakistan floods.

4.5.4 WMO supported PMD to develop an improved proposal for strengthening of PMD capacities to support flood forecasting and warning systems in Pakistan. The proposal was submitted by the Permanent Representative of Pakistan with WMO and the Director General of PMD to the Pakistan Government senior officials and the WB and ADB focal points on 28 September 2010 (*see also paragraph 1.3*).

4.5.5 WMO assisted PMD in the development of a project proposal entitled "Restoring PMD Capacity: Immediate High-Priority Requirements to address Hydro-Meteorological Disaster Risk Reduction (DRR) Challenges in Pakistan" (PC-I Form: *Reference V*), which was submitted to the Planning Commission, Government of Pakistan on 26 October 2010. The proposal contained short-term (October 2010 - June 2011) requirements including restoration of 10 AWSs in flood affected areas; restoration of 10 conventional meteorological observatories in flood affected areas; improvement in warning communication and dissemination system in flood affected areas; and software updating for both hydrological and meteorological models (a total budget of USD 420,000). The mission fully supported this proposal and approach, and considered possible WMO assistance to meet the requirements (*see paragraphs 5.5.2-5.5.3*).

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 General Conclusions

5.1.1 The mission concluded that the flood forecasting services provided by PMD through its extensive network of outreach were appreciated by many key stakeholders. The exceptional situation of the extreme 2010 flood, being the most severe one during the past eight decades, was recognized as a major crisis for the country as well as an important opportunity to modernize the flood forecasting and warning system of the country to prepare for the country to meet new challenges in socio-economic development and climate change.

5.1.2 The rapid assessment of the lessons learned by PMD, which resulted in a new proposal to improve the flood forecasting services together with a new strategy on human resources development for PMD to meet the emerging challenges and the need on decentralization of services, was highly appreciated by all key stakeholders met by the mission. The proposal and related strategy deserve strong support by donor communities and UN organizations.

5.1.3 In order to ensure effective implementation of the PMD proposal and its HRD strategy for decentralization, it is necessary to ensure timely support of the Government and effective integration into the plan for reconstruction and restoration following the 2010 floods as well as in the medium- and long-term plans for socio-economic development and the national programme on disaster risk management. In this regard, through the meetings with senior Government officials, the mission was assured of strong support by the Government.

5.2 Strategy to enhance Capabilities of PMD and to develop Effective Flood Forecasting and Early Warning Systems

5.2.1 The mission, in collaboration with the PMD staff, identified a number of issues that need to be further developed and/or capacity needs to be built, especially on flood forecasting and early warning systems. The mission concluded and recommended the following strategy to enhance capability of PMD and to develop effective flood forecasting and sustainable early warning systems in Pakistan.

Programmatic Issues

5.2.2 The proposed programme to improve flood forecasting and warning services must be fully integrated into the programme of reconstruction and socio-economic development. The programme must aim to achieve the following objectives:

(1) Urgent needs to enhance capacity to cope with the possible floods in 2011 and to support reconstruction and restoration activities;

(2) Emerging needs to support medium-term plan of socio-economic development; and

(3) Long-term needs of a flood-resilient society.

5.2.3 The programme should build on the existing strength of PMD on weather and flood forecasting to provide more effective support to decision-making in disaster risk management at the national, provincial and local levels. The priority areas should include:

- Flash flood early warning;
- Improved hydrometeorological forecasting services;
- Reconstruction of critical observation networks;
- Community-based disaster risk management; and
- Integrated flood management for resilient livelihoods.

5.2.4 The programme should also ensure that solutions are cost effective and sustainable considering PMD's current capacities and what is expected for the future (i.e., in light of projected budget cuts, future budget uncertainties, etc.).

5.2.5 The programme must include a capacity building component. Overall capacity building (e.g., increasing qualified human resources) as outlined by PMD is highly recommended. Forecast communications should be one area of capacity building. A study visit to US National Weather Service Weather Forecast Offices and River Forecast Centres is recommended to learn about forecast operations, warning development and dissemination, and institutional coordination and collaborations.

5.2.6 The programme must always consider applications for a multi-hazard warning system. The need for reservoir management/decision support applications in times of flood and drought should also be considered. This would include application integrated forecast (meteorological and hydrological) and decision support components.

Institutional Issues

5.2.7 Forecasting services related to weather, climate and water are indispensable in the overall national development context. Therefore, PMD needs to be a key driver in disaster risk reduction efforts in close collaboration with government agencies and other partners that are represented in the Federal Flood Commission (FFC), notably including WAPDA. Likewise, close cooperation in planning and decision-making needs to be fostered between NDMA and PMD to ensure field-effectiveness of forecasting services provided by PMD. In this connection, PMD needs to work closely with all stakeholders to develop a firm understanding of their requirements and needs and adjust their operational services accordingly. PMD should educate their stakeholders of their capacities and of what they can achieve and provide.

5.2.8 Recognizing that very different expectations in weather and flood forecasting services exist at different levels from government agencies through district administration authorities and extending to the community and household level, efforts of PMD to decentralize services need to be fully supported. This is expected to generate value-added services as general forecasts can then be tailored towards meeting local demands. In this regard, PMD's operational concepts for decentralization must include the empowerment of regional personnel to act directly with their stakeholders to provide information, data, alerts, warnings, etc. The PMD decentralization process should be implemented on a pilot basis. PMD should open one regional office and operate that office for a period of 1-2 years to develop operational technical and administrative procedures and determine the appropriate requirements for hardware (e.g., computational and radars). Once this pilot office is operating efficiently, then the same approach should be applied to future offices.

5.2.9 In light of the multitude of players in the flood forecasting and warning process and hence different expectations, capabilities, and perception of adequate preparedness and response strategies as well as action-oriented requirements at the district and community levels, it is recommended that the mechanism of institutional cooperation be reviewed and, where

appropriate, strengthened to streamline decision-making and being likewise responsive to local needs.

Technical Issues

5.2.10 Reliable, accurate and timely flood forecasting services are the backbone for sound decision-making in flood management. This requires the update of flood forecasting models and software, the establishment of state-of-the-art flood forecasting tools as well as adequate data management facilities and ensuring fully functional and updated telecommunication facilities for data transmission as well as re-distribution of forecasting results. This needs to be seen in an overall hydrological information system framework that equally integrates meteorological input information in a seamless manner.

5.2.11 Climate variability and change aspects need to be considered, as under climate change there is a high probability that extreme events will occur with a higher frequency and magnitude than under past climate conditions. This has far-reaching consequences including for the design of flood protection measures and overall integrated flood management. In this respect, the programme could be developed as Pakistan's contribution to the WMO-led new initiative of the Global Framework for Climate Services (GFCS).

5.2.12 It is recommended that human resources development (HRD) is a critical component in the overall reconstruction and rehabilitation process. This includes professional training related to forecasting services and integrated flood management practices and likewise comprises communication management and decision-making capabilities as well as awareness building and self-help programme activities at the community and household levels in an effort to manage floods when assistance from government services cannot reach affected communities in a timely manner.

5.2.13 Flood management requires probabilistic approaches to flood mapping and flood zoning so as to actively engage in the use of flood planes, control of flood plane activities and safeguarding critical infrastructure and settlements. There is a highly diverse understanding of risk and acceptance of uncertainties pertaining to the forecasting results.

5.2.14 Total protection from floods is a myth and not achievable with economic means. It is therefore recommended that decision-makers firstly need to understand the uncertainties associated with any forecasting and relating these uncertainties to management decisions. Likewise, there needs to be a harmonization of the risk perception at all levels to rationally and economically provide answers to the question of acceptable risks that arise from the uncertainties of the forecasting process as well as from the probable partial or total failure of flood protection and flood management works and practices. Under the aspect of risk management it is highly recommendable that decision-makers develop management options and provide for planning scenarios, based on hydrometeorological observations and forecasts.

5.2.15 Recognizing that the Indus River basin is highly controlled, it is recommended to review the SOP for dam management with a view to arriving at a basin-wide flexible approach to the management of dams and reservoirs in light of attributing actively to a situation-oriented flood in the Indus River and major tributaries.

5.2.16 In view of different organizations providing hydrological data to PMD for flood forecasting services, it is recommended to review and strengthen the observational network to better serve flood forecasting and also engage in the re-establishment of rating curves for key flood forecasting stations in the main stem of the Indus River and major tributaries.

5.3 Recommended Elements for Action Plan

5.3.1 The recommendations given below are based on the need to make PMD a viable hydrometeorological hazard decision support organization within the government of Pakistan. To address country's need for improvements in disaster risk reduction, PMD must take an active and leading role and improve its capacity to do so.

5.3.2 To improve PMD capacity the following actions, grouped by three categories/phases given in paragraph 5.2.2, are recommended:

Urgent needs to enhance capacity to cope with the floods in 2011 and to support reconstruction and restoration activities

(a) Restoration of damaged observation network of PMD, including 10 AWSs and 10 conventional surface meteorological stations, as given in paragraphs 4.2.5-4.2.7; **[URGENT/HIGHEST PRIORITY]**

(b) Collaboration with WAPDA to replace hydrological monitoring stations (four telemetry stations with telecommunication equipment and 20 hydrometeorological stations) lost in the flood (*see paragraph 4.2.9*) and expand the monitoring network to support improved flood forecasting and warning systems: PMD and WAPDA should develop a strong agreement for the installation (including cross-section measurements to develop rating curves) and maintenance of the stations and for timeliness and quality for data transmission; **[URGENT/HIGH PRIORITY]**

(c) Implementation of a country-wide system for the development of flash flood warnings: This system must address the risk over all flash flood-prone basins within Pakistan. The system must provide the appropriate products for forecasters to make timely and accurate warnings. A system such as the Flash Flood Guidance system, covering the territory of Pakistan and the upper reaches of transboundary rivers, being implemented under a Memorandum of Understanding between WMO, the National Oceanic and Atmospheric Administration (NOAA), the Hydrologic Research Centre and the US Agency for International Development/Office of US Foreign Disaster Assistance would be appropriate to help Pakistan with its flash flood problems; **[URGENT/HIGH PRIORITY]**

(d) Re-evaluation of PMD's current operational concepts (e.g., SOP) for hydrological forecasting with particular attention to the development of bulletins and warnings: In this regard, capacity building is needed on: (i) integrated flood management; and (ii) forecast communications, including forecast operations, warning development and dissemination, and institutional coordination and collaborations (*see paragraphs 5.2.5 and 5.2.7*); **[URGENT/HIGH PRIORITY]**

(e) Careful evaluation of the content and wording of hydrologic- and weather-related informational statements, bulletins, alerts, and warnings to ensure that these statements are clear and concise and appropriately convey the correct message: These messages must also clearly address any uncertainties in forecasts and warnings when appropriate; **[URGENT/HIGH PRIORITY]**

Emerging needs to support medium-term plan of socio-economic development (2-3 years)

(f) Expansion of the Flash Flood Forecasting System currently operational in the Lai Nullah Basin area (for Islamabad and Rawalpindi) to other river basins: This system works well for cities, thus should be duplicated for middle- to large-size cities. Smaller cities and rural communities need a simpler system; **[MEDIUM TERM/HIGH PRIORITY**]

(g) Development of improved numerical weather prediction (NWP) modelling capacity to include the enhancement of a higher-resolution HRM model that can be used in hydrological modelling applications (5-7 km resolution); **[MEDIUM TERM/HIGH PRIORITY]**

(h) Re-evaluation and updating of hydrological modelling capability for river and flood forecasting, including data management practices: PMD must evaluate the weaknesses of the current modelling system during the 2010 flood and modify the models accordingly. At the very least it appears that existing model calibrations need to be improved; **[MEDIUM TERM/HIGH PRIORITY**]

(i) Improvement of warning communication and dissemination system: PMD should evaluate the entire end-to-end hydrological warning process (especially for the quick decisions required for flash floods) and be intimately involved in improving institutional capacity for warnings and evacuations in Pakistan. NDMA should be informed instantly (automatically) for such warning information so that they can take necessary actions including evacuation and rescue/relief operations without delay at the provincial and district levels. A central monitoring system at PMD Head Office on flood warning should be developed; **[MEDIUM TERM/HIGH PRIORITY**]

(j) Decentralization of weather and hydrological forecasting capacities to better address local needs for accurate and timely forecasts and warnings (*see paragraph 5.2.8*); **[MEDIUM TERM/HIGH PRIORITY]**

(k) Enhancement of PMD's current Internet capacity to provide sufficient speed and bandwidth for the transmission of downloaded and uploaded data files and to ensure that products and warnings are transmitted without delay; **[MEDIUM TERM/HIGH PRIORITY]**

(l) Enhancement of PMD's satellite-based flood and drought monitoring capability: PMD, in cooperation with the Space and Upper Atmosphere Research Commission (SPARCO), which is a member of UNESCAP's Regional Cooperative Mechanism on Disaster Monitoring and Early Warning, to establish an operational satellite-based river basin monitoring unit to observe critical variables including rainfall, flood extent and soil moisture, among others; **[MEDIUM TERM/HIGH PRIORITY]**

(m) Capacity building (human resources development) on: numerical weather prediction (NWP) modelling; weather forecasting; hydrology and flood forecasting; **[MEDIUM TERM/HIGH PRIORITY]**

Long-term needs of a flood-resilient society (beyond 3 years)

(n) Replacement of four meteorological radars installed in 1990s at Islamabad, Karachi, D.I. Khan and Rahim Yar Khan with Doppler radars: It is necessary to re-examine the radar siting carefully at each location. Especially for the coastal area, the Karachi site should be relocated considering cyclone impacts. The radar data should be calibrated using observed surface rainfall data; **[LONG TERM/HIGH PRIORITY]**

(o) Capacity building on: NWP (forecasting); hydrometeorology; GIS and remote sensing; glacier monitoring; climate change monitoring; disaster risk management; and maintenance of hydrometeorological equipment. **[LONG TERM/HIGH PRIORITY]**

5.3.3 In addition, an immediate action plan needs to include the following elements, which are stakeholder/PMD action requirements:

- Administrative processes to decentralize forecasting services related to flash floods and riverine floods and setting up of temporary arrangements until the full development of regional and district flood forecasting centres can be fully established;
- Application of integrated flood management principles within the framework of Pakistan's Integrated Water Resources Management (IWRM) priorities;
- Flood mapping and flood plain zoning at least in the most vulnerable areas;
- Review of the operation of dams and reservoirs in support of flood management practices;
- Redesign and reconstruction of dams and levees in hot-spot reaches of the Indus and its tributaries;
- Determination of flows by the establishment of rating curves at key gauging stations;
- Awareness and empowerment activities aiming to strengthen community-based flood management in affected areas;
- Enhancement of medium-range weather forecasting practices in close cooperation with Meteorological Services in the region; and
- Quality assurance of all data used for forecasting purposes.

5.3.4 Noting that measures related to the restoration of livelihoods and securing health and well-being of the affected population is outside the scope of the mission, and in response to stakeholders perception, the following additional recommendations are made:

- To couple flash flood guidance with methods and procedures to estimate landslide, and debris flow hazards that most often are associated with flash floods;
- To intensify sediment load observations and provide solutions to the increasing flood hazard due to sedimentation;
- To strengthen glacier and snow melt observations in support of sustainable water resources management in the mountain areas; and
- To strengthen regional cooperation at all levels and in cooperation with the international community in both scientific aspects of extreme events and operational aspects related to the forecast of floods and droughts including the alleviation of potentially negative effects of man-made intervention in the hydrological system of the Indus basin.

5.4 Assessment of PMD Priority Requirements and Proposed Activities

5.4.1 The mission reviewed the high-priority requirements of PMD to address hydrometeorological DRR challenges in Pakistan (*Reference VI*), developed by PMD in consultation with the WMO Task Force on Pakistan Floods (*see paragraph 1.3*), and considered that the magnitude of necessary assistance was reasonable. The mission endorsed in principle the PMD proposed activities to strengthen PMD capacities for implementing effective flood forecasting and warning systems.

5.4.2 The mission underlined that the urgent needs to enhance flood resilience in the coming floods of 2011 and to ensure effectiveness of reconstruction and restoration on the one hand and the long-term needs to achieve a flood-resilient society on the other require adoption of a strategic approach in the planning and implementation of a programme on improvement of flood forecasting and warning services in the country. For this reason, efforts are being made within the context of the mission to identify key activities and corresponding areas on improvement of PMD flood forecasting services and the corresponding activities by key stakeholders.

5.4.3 The mission, through the coordination/consultation meetings on 4 November 2010, identified several actions to be added under the category - Urgent needs to enhance capacity to cope with the floods in 2011 and to support reconstruction and restoration activities, including:

- Improvement of flash flood forecasting systems (e.g., introduction of Flash Flood Guidance system);
- Improvement of community-based flood forecasting systems, including disaster risk management for priority areas;

- Improvement of flood mapping for priority areas; and
- Technical support to translate flood forecasts to DRR decision-making.

5.4.4 The mission emphasized the need for a phased approach to develop four regional flood forecasting centres. Initial activities should be implemented before the 2011 Monsoon season to establish four regional centres and to mobilize support of local stakeholders. The development of two priority pilot regional flood forecasting centres (e.g., Khyber Pakhtunkhwa and Punjab) was suggested under the category - Emerging needs to support medium-term plan of socio-economic development (2-3 years). Some activities to support disaster risk management were also proposed under this medium-term category.

5.4.5 The assessed needs and estimated costs for improvement of PMD flood forecasting and warning services, based on the PMD high-priority requirements, are given in Appendix VIII. As the entire programme to strengthen flood forecasting and warning services summarized in Appendix VIII is designed to consist of three phases with some initial estimated costs (based on the estimates by PMD), it is expected that the implementation in phases would enable PMD and partners to make direct contribution to the national efforts on urgent rehabilitation, reconstruction and recovery, and disaster risk management for socio-economic development. It is also expected that PMD and partners would learn from the experience of each phase to adjust the scope and details of the subsequent phases. In view of the urgent need to cope with the incoming flood, it is recommended that funds from the Government and collaborating organizations be secured to enable action to be taken as soon as possible.

5.5 Implementation of WMO Technical Assistance Activities

5.5.1 As a general approach for resource mobilization for the implementation of technical assistance activities, it is recommended that on a short-term basis and in cognizance of the little time available for action, best use should be made of already available resources and organizational arrangements while in parallel seeking additional, largely investment-oriented inputs from the international donor community.

5.5.2 WMO assistance will be made, together with UNESCAP and UNESCO, with focus on:

- Observation network rehabilitation, and improved forecasting services including flash floods;
- Capacity building; and
- Regional cooperation and sharing of knowledge.

5.5.3 Recommended assistance with possible mechanisms and procedures for the implementation of support by WMO, Members and potential donors and collaborating partners (UNESCAP and UNESCO) for the current high-priority urgent requirements assessed by this fact-finding mission is presented in Table 2 below.

5.5.4 Further discussions on possible assistance to PMD by WMO, Members and potential donors and collaborating partners as well as resource mobilization activities will be made through the following planned WMO meetings and regional events:

(a) Thirty-eighth session of WMO/ESCAP Panel on Tropical Cyclones (New Delhi, 21-25 February 2011);

(b) UNESCAP Workshop on Developing Capacity for Resilience to Water Related Disasters in Pakistan through Space Applications, Climate Change Adaptation and Flood Risk Management (Islamabad, 1-4 March 2011: to be confirmed);

(c) A side meeting on the 2010 Pakistan floods during the Sixteenth World Meteorological Congress (Geneva, 16 May to 3 June 2011).

Table 2 - Recommended actions for the current urgent, medium- and long-term requirements assessed by this fact-finding mission

Recommendation	***Priority***	***Time-range***	***Proposed solution***	***Funding mechanism***	***Action***
Restoration of 10 AWSs	Highest	Top Urgent	Purchase of 2-3 AWSs and resource mobilization with donor Members for AWSs Expert services with spares for repair of the affected AWSs Government support of funding (PC-I proposal)	WMO Voluntary Cooperation Programme (VCP) and WMO Emergency Assistance Fund (EAF) scheme Government funding	• PMD for VCP request, and WMO and Members for support • PMD for proposal for expert services • Follow up to PC-I proposal
Restoration of 10 conventional meteorological stations	Highest	Top Urgent	Replacement of synoptic station instruments Government support of funding (PC-I proposal)	WMO VCP (to be supported by VCP donors, including China) Government funding	• PMD for VCP request, and WMO to circulate for donors' support • WMO to request China • Follow up to PC-I proposal
Restoration of hydrological monitoring stations	High	Urgent	Procurement of 3 automatic gauging stations	Hindu Kush Himalayan (HKH) HYCOS project	• Consult ICIMOD on fast track procurement
Improvement of warning communication and dissemination system	High	Urgent	Government support of funding (PC-I proposal) Expert services for other solutions	Government funding Expert services under VCP	• PMD for proposals (local quotations) • Follow up to PC-I proposal • PMD to request; suggestion for expert(s)
Forecasting modeling software updates	High	Urgent	Expert services for solutions Government support of funding (PC-I proposal)	VCP and EAF Government funding	• PMD for proposals • Follow up to PC-I proposal
Improvement of flash flood forecasting system	High	Urgent	– Expansion of JICA's flash flood warning system in Lai Nullah Basin to other basins – Introduction of the Flash Flood Guidance system	Japan's Grant Aid mechanism (JICA) Study Visit to USA and training under VCP	• PMD and WMO for Collaboration with JICA • PMD and US Hydrologic Research Centre to make proposal and prepare MoU
Integrated Flood Management (IFM) capacity building	High	Urgent	IFM capacity Building Programme for Planning Commission of Pakistan (Workshop, Islamabad, 11-14 January 2011)	WMO VCP and RB support for resource persons;	• WMO for organization of the Workshop • PMD and Planning Commission for local support
Forecast communication capacity building	High	Urgent	Study visit to US NOAA/NWS	VCP and EAF	• PMD, NWS and WMO for proposal

Appendix I

List of Delegation

Name	*Country/ Organization*	*Official position*	*Address/Tel/Fax/E-mail*
TOYA, Dr Tokiyoshi	WMO Representative	Regional Director for Asia and the South-West Pacific	World Meteorological Organization (WMO) 7 bis, avenue de la Paix Case postale 2300, CH-1211 Geneva 2, Switzerland Tel: +41 22 730 8252 Fax: +41 22 730 8118 E-mail: ttoya@wmo.int
GRABS, Dr Wolfgang	WMO Representative	Chief, Hydrological Forecasting and Water Resources Division, Hydrology and Water Resources Branch	World Meteorological Organization (WMO) 7 bis, avenue de la Paix Case postale 2300, CH-1211 Geneva 2, Switzerland Tel: +41 22 730 8358 Fax: +41 22 730 8043 E-mail: wgrabs@wmo.int
ONO, Dr Yuichi	UNESCAP Representative	Chief, Disaster Risk Reduction Section, Information and Communication Technology and Disaster Risk Reduction Division	UN Building Rajdamnern Nok Avenue Bangkok 10200, Thailand Tel: +66-22881332 Fax: +66-22881085 E-mail: onoy@un.org
LE HUU, Dr Ti	UNESCAP Representative	Chief, Energy Security and Water Resource Section, Environment and Development Division	UN Building Room 506 Rajdamnern Nok Avenue Bangkok 10200, Thailand Tel: +66-2 2881450 Fax: +66-2 2881059 E-mail: ti.unescap@un.org
KOJO, Mr Yoshitomo	Expert, Japan	Head, Aerological Observation Division	Aerological Observatory/Japan Meteorological Agency 1-2 Nagamine, Tsukuba-shi, Ibaraki-ken 305-0052 Japan Tel: +81 29 851-4126 (ext. 214) E-mail : y.kojoh@met.kishou.go.jp
JUBACH, Dr Robert W.	Expert, USA	General Manager, Secretary – Board of Directors	Hydrologic Research Centre 12780 High Bluff Drive San Diego, CA 92130 USA Tel: +1 858-794-2726 Fax: +1 858-792-2519 E-mail **:** rjubach@hrc-lab.org

Note: *Dr Jaser RABADI, WMO Representative for West Asia (relocated at the WMO ad hoc liaison office in Islamabad from 14 October to 13 November 2010 [see paragraph 4.5.3]) joined the mission team.*

Appendix II

Programme of the Mission

Thursday, 4 November 2010

10:00 Opening Remarks — Qamar-uz-Zaman Chaudhry (PR of Pakistan with WMO)
Welcome Remarks — Arif Mahmood (DG of PMD)

10:30 ***PMD COORDINATION MEETING***

1. PMD's National Weather Forecasting Centre, Islamabad — Muhammad Hanif (PMD)

2. Activities of the Federal Flood Commission (FFC) — Alamgir Khan (FFC)

3. Flood Forecasting System — Muhammad Akram Anjum (FFD Lahore)

13:30 *Lunch Break*

14:00 ***COORDINATION/CONSULTATION MEETING WITH STAKEHOLDERS***

- Ministry of Water and Power
- Ministry of Environment
- Planning Commission
- National Disaster Management Authority (NDMA)
- Pakistan Army (Engineer Directorate)
- Federal Flood Commission (FFC)
- Water and Power Development Authority (WAPDA)
- Pakistan Commission for Indus Waters (PCIW)
- Pakistan Council for Research on Water Resources (PCRWR)
- Global Change Impact Studies Centre (GCISC)
- Provincial Irrigation Departments

17:30 Team Meeting

Friday, 5 November 2010

10:30 ***Courtesy Call/Visits to Senior Government Officials***

11:00 Meeting with H.E. Mr Kamal Majidulla, Special Assistant to the Prime Minister on Water Resources and Agriculture

12:15 Meeting with H.E. Dr Riaz Ahmad Khan, Advisor to the Minister of Water and Power

13:00 *Lunch Break*

15:00 Meeting with H.E. Dr Ishfaq Ahmad, Advisor on Science and Technology and Minister of State, Planning Commission

16:00 Meeting with H.E. Lt. Gen. (Rtd) Nadeem Ahmad, Chairman, National Disaster Management Authority (NDMA), Prime Minister's Secretariat, Islamabad

Saturday, 6 November 2010

09:30 Team Meeting

10:00 Technical Tour of PMD Operational Facilities

(a) Research and Development Division
(b) Flood Forecasting and Warning Centre for Lai Nullah Basin
(c) National Seismic Monitoring Centre, Islamabad
(d) National Weather Forecasting Centre

14:00 *Lunch Break*

15:00 ***PMD COORDINATION MEETING***

- Application of Flash Flood Guidance – Presentation by Dr R. Jubach

17:00 Team Meeting

Monday, 8 November

09:30 Team Meeting

10:30 ***Courtesy Call/Visit to Senior Government Officials***

11:00 Meeting with H.E. Lt. General (Ltd) Syed Ather Ali, Secretary, Ministry of Defence

13:00 *Lunch Break*

14:00 Meetings with DNA Focal Points in ADB and UNDP and with JICA

15:00 Finalization of Mission Findings and Recommendations

Appendix III

List of Persons met

Ministry of Defence

H.E. Lt. General (Ltd) Syed Ather Ali, Secretary

Ministry of Defence, Pakistan Meteorological Department (PMD)

Dr Qamar-uz-Zaman Chaudhry, Permanent Representative of Pakistan with WMO

Mr Arif Mahmood, Director General, PMD

Mr Muhammad Akram Anjum, Acting Chief Meteorologist, Flood Forecasting Division, Lahore

Dr Muhammad Hanif, Director, National Weather Forecasting Centre, Islamabad

Mr Azmat Hayat Khan, Director, National Drought Monitoring Centre, Islamabad

Mr Jan Muhammad Khan, Director (Planning), Islamabad

Mr Zahid Rafi, Director (Seismic), Islamabad

Dr Khalid Mahmood, Malik, Director, National Agromet Centre, Islamabad

Mr Ata Hussain, Deputy Director (Coordination & International Cooperation), Islamabad

Prime Minister's Secretariat

H.E. Mr Kamal Majidulla, Special Assistant to the Prime Minister on Water Resources and Agriculture

H.E. Lt. Gen. (Rtd) Nadeem Ahmad, Chairman, National Disaster Management Authority (NDMA)

Mr Ahmed Kamal, Member (Admin & Finance), NDMA

Planning Commission

H.E. Dr Ishfaq Ahmad, Advisor on Science and Technology and Minister of State

Mr Naseer Gillani, Chief (Water)

Ministry of Water and Power

H.E. Dr Riaz Ahmad Khan, Advisor to the Minister of Water and Power

Mr Alamgir Khan, Chief Engineer, Federal Flood Commission (FFC)

Mr Mushtaq Ahmad, Chief Engineer (H&WM), Water & Power Development Authority (WAPDA), WAPDA House, Lahore

Mr Tahir Waseem, Joint Commissioner, Pakistan Commission for Indus Waters (PCIW), Lahore

Pakistan Army

Col. Ibrar Ahmed, Engineers Directorate, General Headquarters, Rawalpindi Cantt.

Ministry of Environment

Mr Munir Sheikh, Head, Climatology Section, Global Change Impact Studies Centre (GCISC), Islamabad

Mr Ghazanfar Ali, Head, Water Resources Section, GCISC, Islamabad

Ministry of Science and Technology

Dr A.D. Khan, Pakistan Council for Research on Water Resources (PCRWR), Islamabad

Ministry of Information Technology and Telecom

Mr Ali Mehmud, Director (Telecom)

Ministry of Foreign Affairs

Mr Hussain Muhammad, Assistant Director (UN-III)

Provincial Irrigation Department, Government of Punjab, Lahore

Mr Rafique Ahmad, Chief Engineer (Floods), Lahore

Provincial Irrigation Department, Government of Khyber Pakhtunkhwa, Peshawar

Mr Izzat Khan, Executive Engineer (Hydrology), Peshawar

Provincial Irrigation Department, Government of Balochistan, Quetta

Mr Muhammad Waseem Asghar, Provincial Coordinator

UNESCO

Dr Shahbaz Khan, UNESCO, Paris

Mr Arslan, UNESCO Office, Islamabad

UNDP

Mr Toshihiro Tanaka, Country Director, UNDP Islamabad

Mr Anwar ul Haq, Recovery Advisor, Office of Resident Coordinator

Asian Development Bank (ADB)

Mr Mian Shaukat Shafi, Team Leader, Earthquake Emergency Assistance Unit, Pakistan Resident Mission

Japan International Cooperation Agency (JICA)

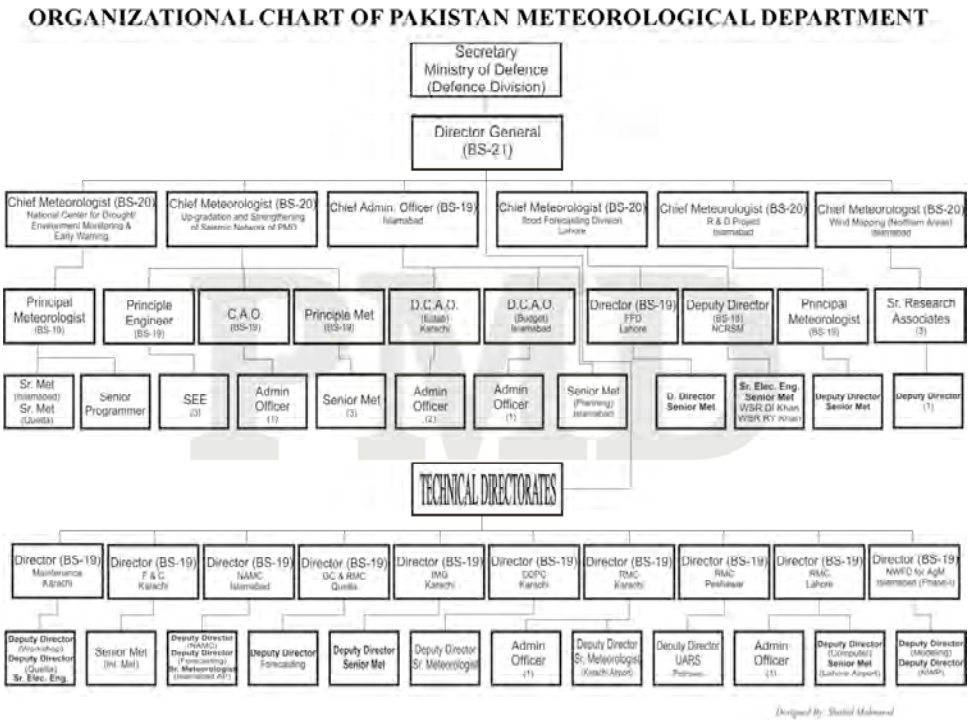
Mr Tomohiro Kozono, Representative, JICA Pakistan Office

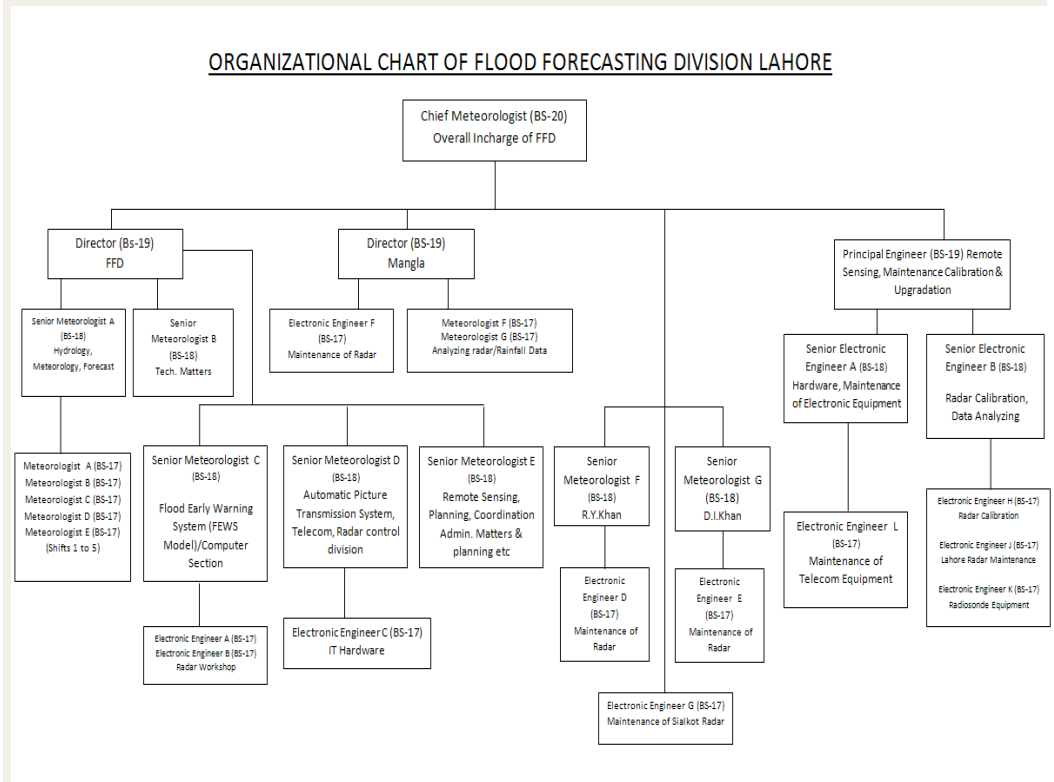
Mr Ichiro Kobayashi, Team Leader, JICA Expert Team, NDMA

Mr Kazuto Suzuki, Deputy Leader/Early Warning System, JICA Expert Team, NDMA

Appendix IV

Organizational Charts of PMD and FFD Lahore



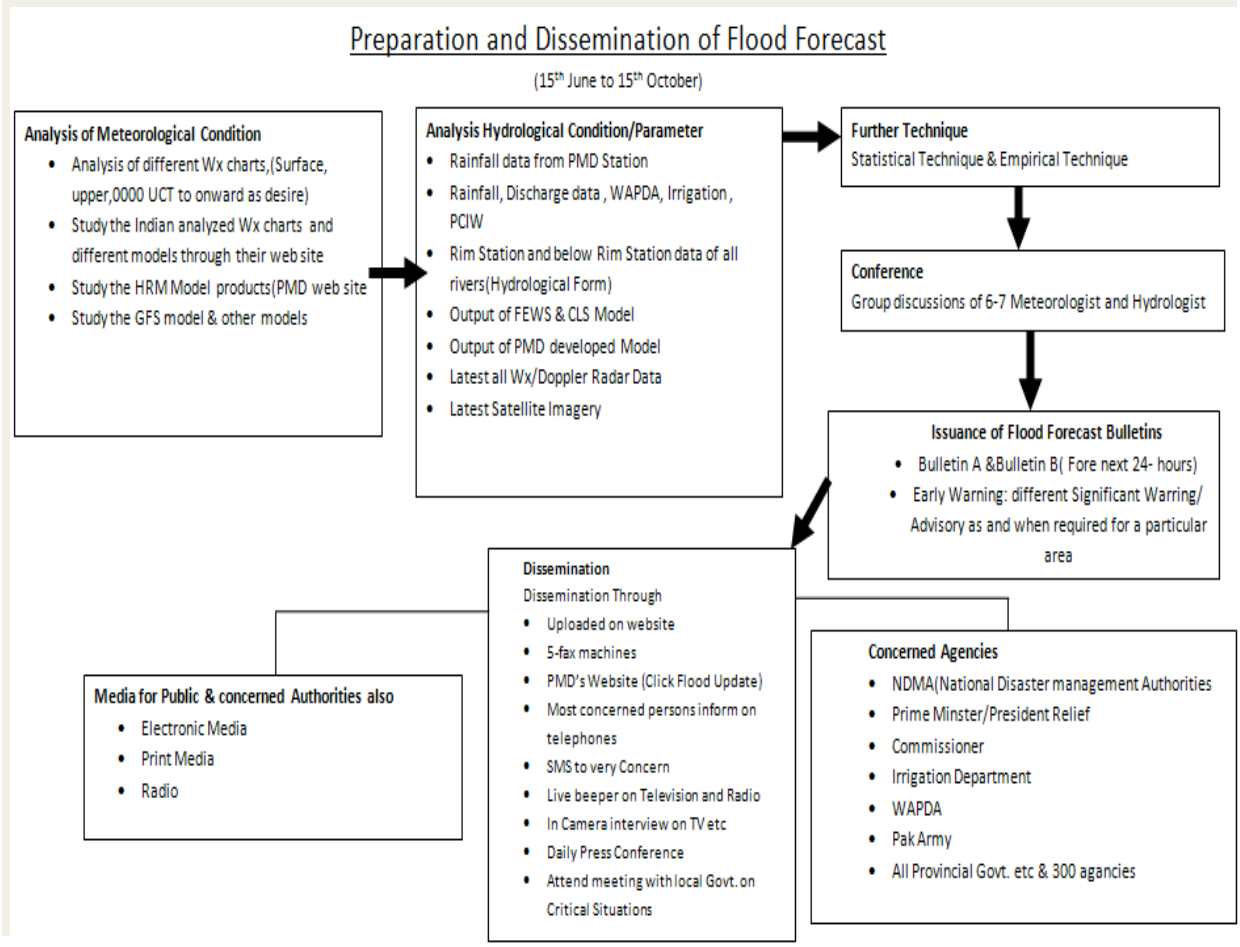


Appendix V

Personnel and Budget Allocations

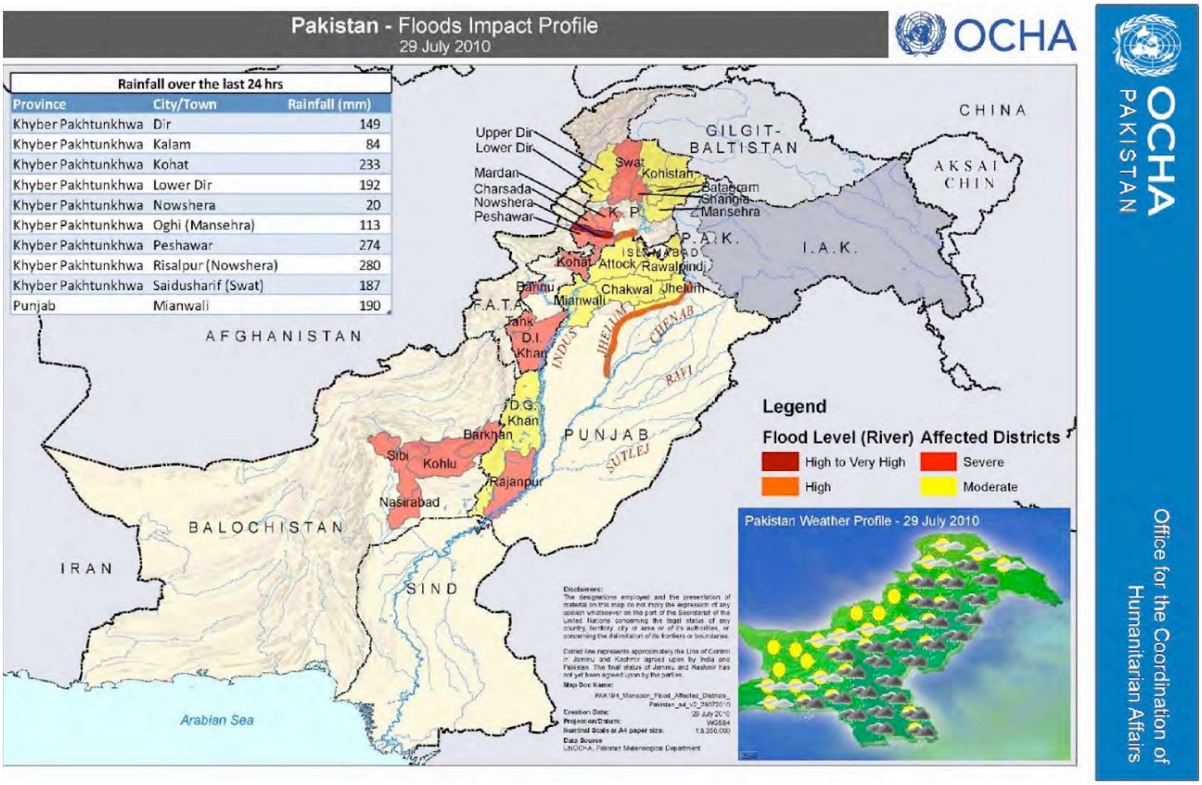
Financial Year	PMD strength (Officer & Staff)	Development Budget	Non-development Budget
2009-2010	353+2208=2561	Rs. 365,535,000	Rs. 417,880,000
2008-2009	415+2276=2691	Rs. 662,736,000	Rs. 394,991,000
2007-2008	363+2231=2594	Rs. 467,035,000	Rs. 352,828,000
2006-2007	351+2233=2584	Rs. 267,471,000	Rs. 322,652,000
2005-2006	350+2233=2583	Rs. 165,531,000	Rs. 264,288,000
2004-2005	301+1979=2280	Rs. 79,495,000	Rs. 223,439,000
2003-2004	301+1979=2280	Rs. 32,385,000	Rs. 187,903,000
2002-2003	301+1978=2279	Rs. 4,038,000	Rs. 180,924,000
2001-2002	232+1981=2213	Rs. 9,800,000	Rs. 156,102,000

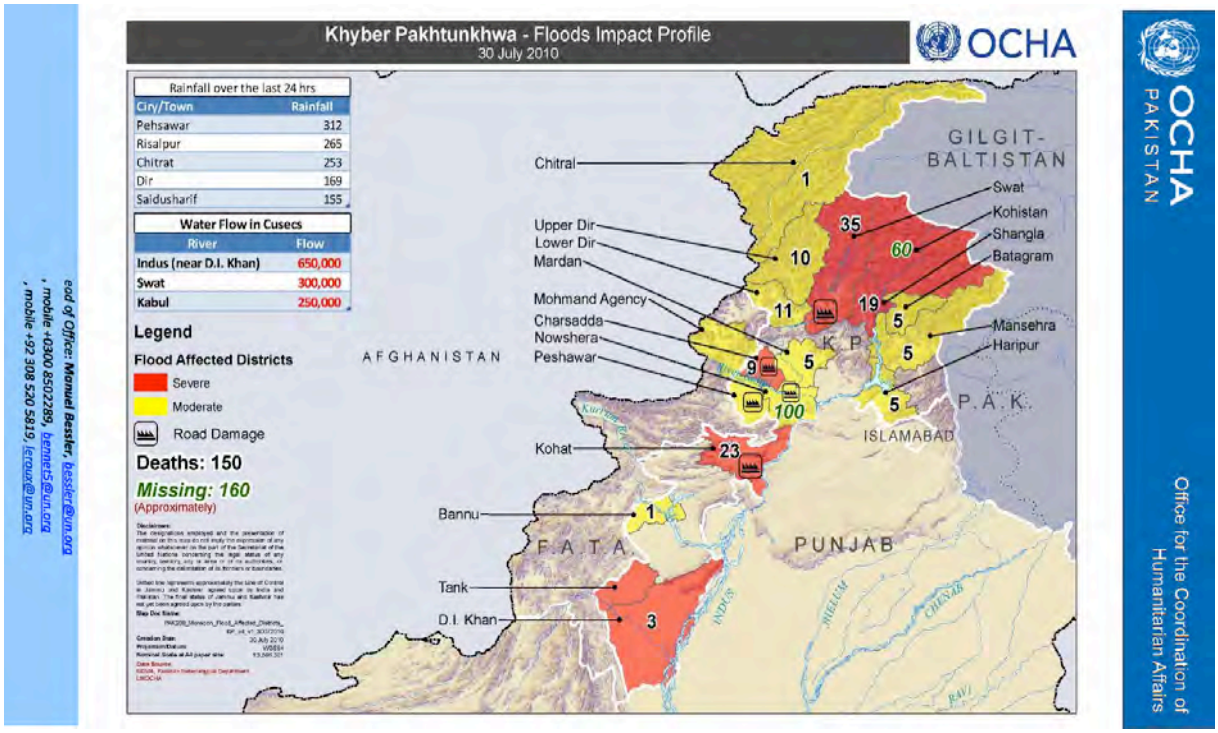
Appendix VI



Appendix VII

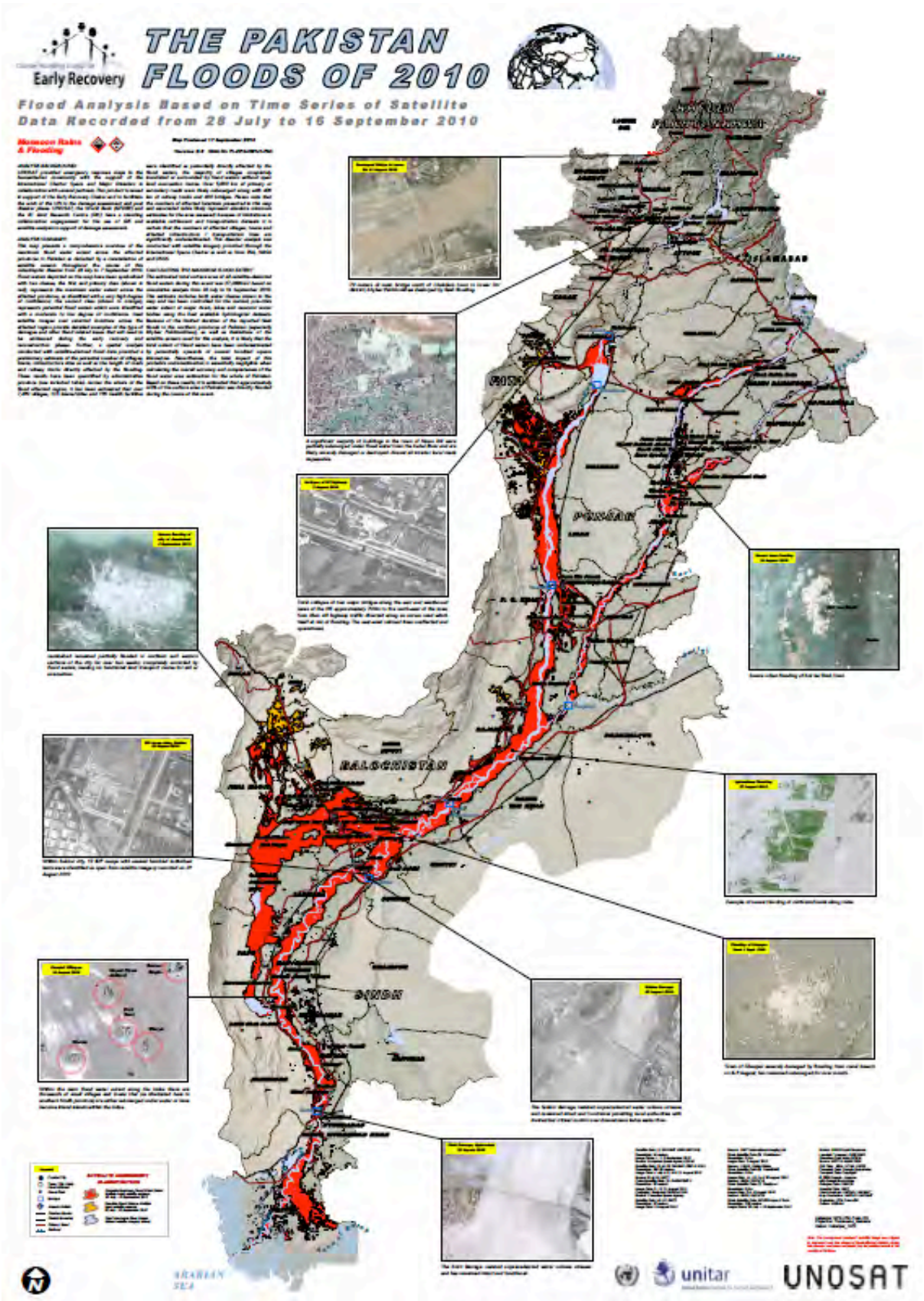
Floods Impact Profile of Pakistan and Khyber Pakhtunkhwa





eod of Office: Manuel Bessler, bessler@un.org
, mobile +0300 8502289, benne15@un.org
, mobile +92 308 520 5819, leroux@un.org

Flood Analysis based on Time Series of Satellite Data recorded from 28 July to 16 September 2010



Note: This map is available at UNOSAT Website: http://unosat-maps.web.cern.ch/unosat-maps/PK/FL20100802PAK/UNOSAT_PAK_FL2010_EarlyRecoveryOverview_v2_HR.pdf

Appendix VIII

Key Needs for Improvement of PMD Flood Forecasting and Warning Services

Urgent needs to enhance capacity to cope with the floods in 2011 and to support reconstruction and restoration activities

a	***Meeting the needs of stakeholders based on experiences of the 2010 floods***	**USD million**
1	Restoration of Ten (10) Automatic Weather Stations (AWSs) in flood affected areas	0.15
2	Restoration of Ten (10) conventional Met. Observatories in flood affected areas	0.07
3	Restoration of hydrological monitoring stations in flood affected areas	0.80
4	Improvement in warning communication and dissemination system in flood affected areas	0.05
5	Software updating (both meteorological and hydrological models)	0.15
6	Improvement of flash flood forecasting systems	0.35
7	Study on possibility to improve early warning for landslide hazards	0.05
	SUB-TOTAL	***1.62***
b	***Meeting the needs of stakeholders on flood forecasting and warning services***	
8	Initial activities to establish the four regional flood forecasting centres and to mobilize support of local stakeholders	2.00
9	Improvement of community-based flood forecasting systems, including disaster risk management for priority areas	0.30
10	Improvement of flood mapping for priority areas	0.20
	SUB-TOTAL	***2.50***
c	***Priority activities of PMD to improve forecasting services***	
11	Technical support to translate flood forecasts to DRR decision-making	1.00
	SUB-TOTAL	***1.00***
	TOTAL	**5.12**

Emerging needs to support medium-term plan of socio-economic development (2-3 yrs)

a	***Meeting the needs of stakeholders based on experiences of the 2010 floods***	**USD million**
1	Full-scaled development of two priority pilot regional flood forecasting centres (e.g., Khyber Pakhtunkhwa and Punjab)	8.00
2	Capacity building to prepare for the development of two other regional flood forecasting centres	1.00
	SUB-TOTAL	***9.00***
b	***Meeting the needs of stakeholders on flood forecasting and warning services***	
3	Further development of the flash flood forecasting systems, including technology transfer	4.40
4	Development of early warning systems for landslide hazards, including landslide hazard mapping and land-use control	0.80
	SUB-TOTAL	***5.20***

c	***Core activities of PMD to improve forecasting services***	
5	Medium-term Technical Human Resource Development for PMD	1.53
6	Strengthening of PMD's warning communication and dissemination system	6.71
	SUB-TOTAL	***8.24***
d	***Establishing foundation for flood resilience society***	
7	Development of improved decision-support systems for operations of major reservoir for more effective risk management with improved forecasting support systems	2.00
8	Improvement of institutional capacity in flood forecasting operation rules based on latest developments in forecasting services	1.00
9	Support for other DRR-related risk management	0.20
	SUB-TOTAL	***3.20***
	TOTAL	**25.64**

Long-term needs of a flood-resilient society (beyond 3 years)

a	***Meeting the needs of stakeholders on flood forecasting and warning services***	**USD million**
1	Completion of the four regional flood forecasting centres	17.00
2	Further development and capacity building for flash flood forecasting and land slide forecasting services	4.00
3	Further support to multi-hazard decision-making for DRR	2.00
4	Support of human resources development for decentralization of flood forecasting and warning services and capacity building on disaster risk management	2.00
5	Further support to flood plain mapping and monitoring	1.00
	SUB-TOTAL	***26.00***
b	***Framework for a long-term programme of PMD to improve forecasting services***	
6	Numerical Weather Prediction / Forecasting - Capacity Building	0.56
7	Hydrometeorology / Hydrology - Capacity Building	0.70
8	GIS / Remote Sensing - Capacity Building	0.42
9	Glacier Monitoring / Snow Melting - Capacity Building	0.42
10	Climate Change / Monitoring - Capacity Building	0.56
11	Maintenance of installed Automatic Weather Stations with Spares	0.02
12	Maintenance of installed Radar Network and Spares	0.60
13	Maintenance of equipment installed under Flash Flood Forecasting Stations along with required Spares	0.80
14	Maintenance cost of equipment installed under conventional meteorological observatories & required Spares	0.02
15	Establishment of Specialized Medium-Range Forecasting Centre	4.65
	SUB-TOTAL	***8.75***
c	***An integrated flood management programme for flood resilience society***	
16	Strengthening of capacity for drought monitoring and forecasts	1.50
17	Technical Human Resource Development for integrated flood management and decision support tool development	1.00
	SUB-TOTAL	***2.50***
	TOTAL	**37.25**

	GRAND TOTAL	**68.01**

Appendix IX

References

Reference I Tool for Assessment of Institutional Capacities in Early Warning Systems (completed by PMD)

Reference II Tool for the Assessment of Capacities of National Meteorological and Hydrological Services (completed by PMD)

Reference III Pakistan Floods 2010 – Damage Assessment Form for Flood Forecasting Telemetry Stations (prepared by WAPDA)

Reference IV Financial Impacts of the Losses due to Flood Damage in respect of Surface Water Hydrology Project of WAPDA (prepared by WAPDA)

Reference V "Restoring PMD Capacity: Immediate High-Priority Requirements to address Hydro-Meteorological Disaster Risk Reduction (DRR) Challenges in Pakistan" (PC-I Form) (prepared by PMD)

Reference VI High Priority Requirements of PMD to Address Hydrometeorological DRR Challenges in Pakistan (prepared by PMD)

Note: The above documents are available upon request.

Appendix X

Abbreviations

ADB	*Asian Development Bank*
AWSs	*Automatic Weather Stations*
CER	*Cabinet and External Relations (WMO)*
D.I.	*Dera Ismail (Pakistan)*
DNA	*Damage and Needs Assessment*
DRA	*Development and Regional Activities (WMO)*
DRR	*Disaster Risk Reduction*
EAF	*Emergency Assistance Fund (WMO)*
ESCAP	*Economic and Social Commission for Asia and the Pacific*
FATA	*Federally Administered Tribal Areas (Pakistan)*
FEWS	*Flood Early Warning System*
FFC	*Federal Flood Commission (Pakistan)*
FFD	*Flood Forecasting Division (Pakistan)*
FFWMCC	*Flood Forecasting and Warning Master Control Centre (Pakistan)*
GCISC	*Global Change Impact Studies Centre (Pakistan)*
GFCS	*Global Framework for Climate Services (WMO)*
GPRS	*General Packet Radio System*
HRD	*Human Resources Development*
HRM	*High-resolution Regional Model*
HWR	*Hydrology and Water Resources*
IFM	*Integrated Flood Management*
IWRM	*Integrated Water Resources Management*
JICA	*Japan International Cooperation Agency*
KPK	*Khyber Pakhtunkhwa (Pakistan)*
MBC	*Meteor-Burst-Communication*
NDMA	*National Disaster Management Authority (Pakistan)*
NOAA	*National Oceanic and Atmospheric Administration*
NPCC	*National Power Construction Corporation (Pakistan)*
NSMC	*National Seismic Monitoring and Tsunami Warning Centre (Pakistan)*
NWP	*Numerical Weather Predication*
OCHA	*Office for Coordination of Humanitarian Affairs*
PAF	*Pakistan Air Force (Pakistan)*
PCIW	*Pakistan Commission for Indus Waters (Pakistan)*
PCRWR	*Pakistan Council for Research on Water Resources (Pakistan)*
PDMA	*Provincial Disaster Management Authority (Pakistan)*
PMD	*Pakistan Meteorological Department (Pakistan)*
PTC	*Panel on Tropical Cyclones*
RAP	*Regional Office for Asia and the South-West Pacific (WMO)*
SMS	*Short Message Service*
SOP	*Standard Operating Procedures*
SPARCO	*Space and Upper Atmosphere Research Commission (Pakistan)*
TCWC	*Tropical Cyclone Warning Centre (Pakistan)*
UN	*United Nations*
UNDP	*United Nations Development Programme*
UNESCO	*United Nations Educational, Scientific and Cultural Organization*
UNOSAT	*United Nations Institute for Training and Research (UNITAR) Operational Satellite Applications Programme*
VCP	*Voluntary Cooperation Programme (WMO)*
VSAT	*Very Small Aperture Terminal*
WAPDA	*Water and Power Development Authority (Pakistan)*
WB	*World Bank*
WDS	*Weather and DRR Services (WMO)*
WFP	*World Food Programme*
WMO	*World Meteorological Organization*