特 集 4
研究解説
UDC 614.8 : 551.58 : 627.51

Floods and Cyclones Disasters in Bangladesh

バングラデッシュにおける洪水とサイクロン災害

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Salient features of floods and cyclones disasters in Bangladesh are briefly described. Flat and low topography, shallow and funnel shaped Bay of Bengal, high density of population are some of the major characteristics of Bangladesh. A systematic study and research on disasters in Bangladesh is very much needed, and INCEDE could play a vital role in disseminating information and knowledge related to disasters, through joint research projects of mutual interest.

1. Introduction

Bangladesh is a disaster-prone country with high density of population (about 800 persons/km^2) having an area of 144,000 km^2 and a population of about 110 million. The physiography, morphology and other conditions have made her vulnerable to disasters like floods, droughts, windstorms (cyclones/storm surges/tornadoes) and others which occur regularly and frequently. Major factors responsible for disasters are:

- Flat topography
  –more than 50 percent of the area having less than 10m elevation with highest flat-plain area of the order of 100m (highest peak about 1004m-Mowdok Mual); 12 percent hilly region, 8 percent old Pleistocene region and 80 percent recent alluvium region(1).
- Rapid run-off and drainage congestion
  –extremely low relief of the flood plains between 1 and 2m and low-river gradients–3 cm/km for the Meghna, 4–5 cm/km for the Ganges and 6-10 cm/km for the Brahmaputra (2).
- Effects of the confluences of the major rivers-system (The Ganges-Brahmaputra-Meghna-GBM-delta) with a vast network of rivers.
  – the tributaries and distributories of the GBM delta that are criss-crossing the country with a large number of islands in between the channels.
- Enormous discharge of river-water heavily laden with sediments.
  – both suspended and bed load (order of 2.4 billion tons per year).
- Funnel-shaped and shallow northern Bay of Bengal causing strong tidal and wind actions and amplifying the effects of cyclones and storm surges.

These factors act in complicated ways to bring about geomorphological changes in the Bangladesh coastal areas. Based on the available information of the morphological conditions and hydrological features, the coast of Bangladesh covering about 710 km could be divided into three broad regions: Eastern Region, Central Region and Western Region—each having special characteristics, making them more vulnerable to disasters particularly to cyclones and associated storm surges causing huge loss of human lives, physical properties and infrastructure facilities.

In the present paper an attempt has been made to highlight various aspects of floods and cyclones disasters in Bangladesh and their impacts and possible international cooperation including INCEDE's role in disaster-mitigation.

2. Disasters in Bangladesh

Disasters have global impact. Most of the Asian countries are disaster-prone. The physiography, morphology and other natural conditions have made them vulnerable to disasters and environmental hazards. The major universal disasters are:

- Floods.
- Windstorms (typhoons/cyclones/tornadoes) and storm

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surges.
- Droughts.
- Abnormal rainfall, hailstorm and lightning.
- Erosion and landslides.
- Earthquakes, tsunamis and volcanic eruptions.
- Saline intrusion.
- Industrial and other pollution.
- Deforestation and depletion of forests.
- Environmental degradation and hazards connected with disturbances in eco-balances, i.e. ecological imbalance.
- Greenhouse gases, global warming, sea level rise, depletion of ozone layer, etc.
- Effects of El-Nino-Southern Oscillation (ENSO) and other climatic changes, variability and anomalies.

It may be mentioned that almost all of the above disasters occur in Bangladesh except tsunamis, volcanic eruptions and landslides. Floods and cyclones are regular and frequent due to peculiar geographic location of Bangladesh. They have disastrous effects on life and property and offset development efforts particularly of the developing countries like Bangladesh. Satellite remote sensing could play a vital role in the early warning, pre- and post-disaster events, damage assessment and other related activities. Satellite information/data are available in Bangladesh area since mid-1960's with the establishment of an APT (Automatic Picture Transmission) system in the country. Since then the system was updated in 1970's and 1980's with the changes of satellite configuration and transmission techniques. These systems have been able to track and monitor all the cyclones formed in the Bay of Bengal since mid-1960's. They have been successfully used for forecasting, monitoring and management of the devastating cyclones of 1970, 1985 and 1991 as well as the unprecedented floods of 1974, 1987 and 1988. The extensive use of Landsat and SPOT satellites data for disasters management, monitoring, reconstruction and other related activities started in Bangladesh in early 1970's. Recently introduction of GIS (geographic information system) has enriched the local capability to a greater extent. The integrated use of RS-GIS and other conventional data including socio-economic information is playing a vital role in the national planning and development activities in Bangladesh.

2.1 Floods in Bangladesh

Floods frequently and regularly occur in Bangladesh. Though monsoon rains are the major causes of flooding, there are various other factors like rapid runoff, the effect of the confluences of the major rivers, the flat topography of the delta and surges in the Bay of Bengal. Types of flooding in Bangladesh are:

- Flash floods - sharp rise and drop in water levels causing high velocity damaging crops and property.
- Rain floods - high intensity rainfall over Bangladesh and surrounding area.
- Monsoon floods - over spilling of major rivers which usually rise slowly but extensive damage occurs when the three major rivers rise at a time.
- Storm surge floods in the coastal area.

The peculiar geographic location and low topography of Bangladesh area (3 & 4) have subjected her to flooding from time immemorial. The severe and extensive flooding in the Bangladesh area occurred in the years 1787, 1871, 1885, 1892, 1918, 1922, 1954, 1955, 1963, 1968, 1969, 1970, 1971, 1974, 1987 and 1988. It should be noted that intervals between severe flooding are becoming shorter with the increase of population.

1987 Flood

The 1987 flood commenced in the third week of June and lasted until the end of September. The earliest flood hit the northern parts of Bangladesh. The Brahmaputra, the Ganges, and the Meghna reached their respective bankfull stages in the last week of July and the beginning of August. Following that, water levels rose rapidly and the peak discharges in these rivers were recorded within a week of each other: on 12 August in the Brahmaputra (74,800 m^3/sec), on 16 August in the Meghna (16,000 m^3/sec), and on 19 August in the Ganges (76,000 m^3/sec) (5). Their combined peak flow (166,800 m^3/sec) exceeded the previous record of 160,000 m^3/sec. All major rivers maintained their high levels throughout the months of August and September. One of the unique features of the 1987 flood was that the northwestern districts of Bangladesh, which remain normally flood-free, experienced prolonged flooding from the tributaries of the Brahmaputra and the Ganges. In the middle of August major floods were reported by newspapers from three areas. In the northwestern region, the Ganges and the Brahmaputra and many of their tributaries exceeded their record water levels, causing extensive overbank inundation (6). In the central region, extensive flooding was reported along the lower reaches of the Brahmaputra, Ganges and

Meghna rivers. Reports also confirmed deep flooding along the tributaries of the Meghna in the northeastern region. Large parts of the Barind tract in the northwest, which remain normally flood-free, show evidence of shallow flooding. The total area affected by the flooding on 18 August, as determined by planimetric computation of three categories of flood areas on the satellite imagery, was approximately 50,500 km^2 (35% of Bangladesh). The official estimate of the maximum extent of flooding in 1987 was 57,300 km^2 (40% of Bangladesh) (5). However, the accuracy of this estimate could not be verified through satellite imagery alone since it was based on varied sources of information.

1988 Flood

The 1988 flood was the most catastrophic flood of this century. The flood commenced in early July, but the record high water levels were achieved relatively late in the summer by rapid synchronization of peak flows in the Brahmaputra (99,500 m^3/sec), the Ganges (72,300 m^3/sec), and the Meghna (19,000 m^3/sec) within a period of 72 hr between 30 August and 2 September (7). The combined peak flow of the three rivers (190,800 m^3/sec) exceeded the 1987 record-high flow by a significant margin and, thus, set a new 100-year record. The flood also set another 100-year record by inundating an estimated area of 82,000 km^2 (57% of Bangladesh), which surpassed the previous records of the extent of 1955 and 1987 flooding (36% and 40%, respectively). Figure 1 shows the maximum extent of 1988 flooding and 1955 flooding. It should be stressed, however, that this area was estimated by Bangladesh Water Development Board (BWBD) by using a number of sources of information. The visual interpretation of selected Advanced Very High Resolution Radiometer (AVHRR) was done to monitor the fluctuating extents of flooding for specific imagery dates. For this purpose, river gauge measurements and newspaper reports on the day-to-day progress of flooding were correlated with the satellite imagery.

Figure 2 is a typical example of flood area delineation from an AVHRR image by visual interpretation. The computed flood areas on different dates varied significantly during the recession period, indicating the dynamic nature of the flood event. These data suggest that the flood started receding slowly through a period of secondary peaks (such as that of 15 September). By 24 September, the extent of flooding was considerably less than that of 10 September, although large areas were still under water (Figure 2).

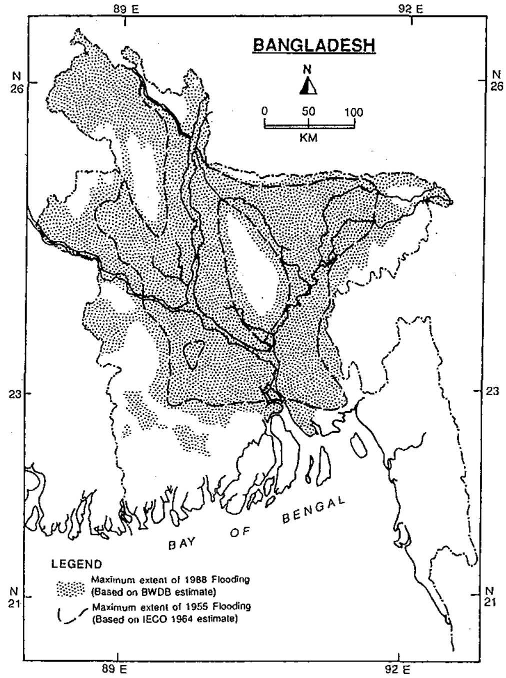

Fig. 1 Maximum extents of 1988 and 1955 flooding. The 1988 flood boundary was based on varied sources of information, including satellite imagery; the 1955 boundary was determined by conventional ground information.

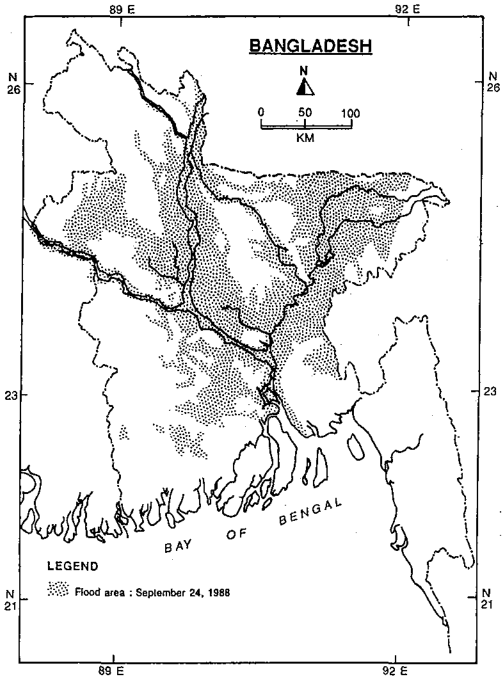

Fig. 2 Flood area on 24 September 1988 based on visual interpretation of the AVHRR imagery from the NOAA-10 morning pass for that date.

2.2 Cyclones in Bangladesh

Every year, there are some eighty tropical cyclones occurring around the globe, out of which about 4 form in the Bay of Bengal (8). The formation, intensification and structure of tropical cyclones are related to six primary climatological genesis parameters which are (9):

- Low level relative vorticity.
- Coriolis parameter.
- Weak vertical shear.
- Ocean thermal energy - sea surface temperature more than 26°C.
- Vertical gradient of equivalent potential temperature.
- Middle tropospheric relative humidity.

Technically, a cyclone is an area of low pressure where strong winds blow around a center in anti-clockwise direction in the northern hemisphere and clockwise direction in the southern hemisphere. Tropical cyclones derive their energy from warm moisture of the sea and to sustain this energy, sea temperature needs to be at least 26°C. Tropical cyclones weaken rapidly when moving over cooler overland. Low level winds must converge into an area of disturbed weather to provide some initial rotation. Developing tropical depression needs a continuing spiral inflow to supply momentum and water vapor to the spinning vortex (8 & 10).

The Bay of Bengal is situated in the north-eastern corner of the Indian ocean and is bounded between latitudes 5–22 degrees north and longitudes 80–95 degrees east. It occupies an area of about 2.2 million km^2. It is 1609 km wide with average depth of 790 m and maximum depth is 4500 m (11). The Bay of Bengal cyclones mostly originate at latitudes greater than five degrees north (near the Andamans). It is presumed that the Inter-Tropical Convergence Zone (ITCZ) which is situated near the equator and where the winds from the two hemisphere meet plays a part in the formation of the tropical cyclones. The Bay of Bengal is the breeding place of catastrophic cyclones causing loss of life and property during pre-monsoon (April-May) and post-monsoon (September-December) periods. Cyclones in the Indo-Bangladesh sub-continent are classified according to their intensity and the following nomenclature is used:

- Depression - winds up to 62 km/hr.
- Cyclonic storm - winds between 63-87 km/hr.
- Severe cyclonic storm - winds between 88 - 118 km/hr.
- Severe cyclonic storm of hurricane intensity - winds above 118 km/hr.

Normally it is observed that cyclones at their initial stages move at a rate of 8–16 km/hr and in their final stages move at a rate of 24–32 km/hr or even up to 48 km/hr. The cyclones usually decay after crossing the land causing colossal damages to life and property in the coastal region. They are accompanied by heavy rains and tidal waves called storm-surges which cause most of the damages. Storm surge-heights are directly related to the cyclone intensity. If the strength of the wind in a cyclone increases, the surge-height will also increase. Astronomical tides in combination with surge-height lead to higher water-levels and hence severe flooding.

It may be mentioned that on average 1.5 severe cyclonic storms hit Bangladesh each year and associated storm-surges, as much as 6m, can reach as far as 200 km inland(12). Catastrophic cyclones occurred in the Bay of Bengal and hit Bangladesh coastal areas in the years 1584, 1876, 1919, 1942, 1960,1961, 1963, 1965, 1970, 1985, 1988 and 1991. Again, intervals have become shorter in recent years. Some of major cyclones affecting Bangladesh coastal areas with dates, maximum wind speeds, surge -heights and death toll are given in Table 1 (13,14, 15 &16).

The cyclone that crossed Bangladesh coast during the night of 29-30 April 1991 was devastating and unprecedented. The maximum wind speed observed at Sandwip was 225 km/hr but the actual wind speed could have been higher (estimated to be 235 km/hr) - as the wind measuring device was blown away after this speed was recorded. The maximum storm surge-height during this cyclone has been estimated to be about 6.1 to 7.6m. The loss of human lives was estimated to be 140,000 (official estimate 138,000) and total loss of property was of the order of US$ 1,385 million (15 & 17). Satellite imagery of 29-30 April 1991 cyclone and its track are shown in Figs. 3 and 4 (18 & 19).

3. Disaster Forecasting and Warning System in Bangladesh

Bangladesh Meteorological Department (BMD) is responsible for normal day-to-day weather forecasting and cyclone/storm warning in the country. The Storm Warning Center of BMD is the focal point of these activities. Flood forecasting is the responsibility of the Bangladesh Water Development Board (BWDB) and environmental problems are tackled by the Department

90 × 48 = 4320

of Environment (DOE). The National Disaster Prevention Council has overall responsibility for policy guidance, inter-ministerial coordination, implementation of disaster relief operations. Ministry of Relief and Rehabilitation coordinates relief and rehabilitation activities. A number of other government agencies and non-governmental organizations are also associated with disaster management and relief and rehabilitation operations. The flow-diagram and interactions between different agencies are explained in Appendix-A.

Bangladesh Space Research and Remote Sensing Organization (SPARRSO) has the facilities for RS-GIS which has been used for prediction and warning of cyclones particularly the super cyclone of 1991. It was tracked since April 23, 1991 though it hit on the night of 29-30 April 1991. In addition RS-GIS facilities available in other organizations like Bangladesh Agricultural Research Council, Local Government Engineering Department, etc. have also been used for rehabilitation and reconstruction activities. RS-GIS along with socio-economic and other conventional information/data are being used as resource data base for planning, monitoring, management and development activities in the country.

4. Lessons Learnt from Past Disasters

The extent of damages caused by floods and cyclones in Bangladesh is catastrophic in nature. The value of destroyed assets in any one disaster event is more than the overall annual development budget earmarked for socio-economic development in the country. The net effects are retardation of development and rebuilding of infrastructure facilities which need huge resources. This is happening in a vicious cycle resulting in more poverty and miseries of the people in an increased magnitude. To cite examples, in the 1970 cyclone, it was estimated that 500,000 people were killed and the total loss of property was of the order of US$ 1,000 million. It is further estimated that the total loss of physical property in Bangladesh due to natural disasters from 1947 to 1991 is of the order of US$ 25 billion. In addition about a million valuable human lives were lost and unquantifiable ecological and environmental degradation was caused by natural disasters in the country (20, 21 & 22). It is stated that huge loss of human lives during any disaster is also due to the high density of population throughout the country. Other factors of importance in disaster management in Bangladesh are extreme poverty of the people,

Table 1 MAJOR CYCLONES IN BANCLADESH SINCE 1960

Major cyclones in Bangladesh since 1960 (Choudhury [1991], supplemented by Bangladesh Meteorological Department [1990] data)

Date		Maximum wind speed (m/s)	Storm surge height (m)	Number of deaths
Oct. 9,	1960	45.0	3.0	3,000
Oct. 30,	1960	58.3	4.6–6.1	5,149
May 9,	1961	40.6	2.4–3.0	11,466
May 30,	1961	40.6	6.1–8.8	—
May 28,	1963	56.4	4.3–5.2	11,520
April 11,	1964	—	—	196
May 11,	1965	45.0	3.7	19,279
May 31,	1965	—	6.1–7.6	—
Nov. 5,	1965	44.4	2.4–3.7	—
Dec. 14,	1965	58.3	4.6–6.1	873
Oct. 1,	1966	40.6	4.6–9.1	850
Nov. 1,	1966	33.3	6.1–6.7	—
Oct. 11,	1967	—	1.8–8.5	—
Oct. 24,	1967	—	1.5–7.6	—
May 10,	1968	—	2.7–4.6	—
April 17,	1969	—	—	75
Oct. 10,	1969	—	2.4–7.3	—
May 7,	1970	—	3.0–4.9	—
Oct. 23,	1970	45.3	—	300
Nov. 12,	1970	61.9	6.1–9.1	500,000
May 8,	1971	—	2.4–4.3	—
Sep. 30,	1971	—	2.4–4.3	—
Nov. 6,	1971	—	2.4–5.5	—
Nov. 18,	1973	—	2.4–4.0	—
Dec. 9,	1973	33.9	1.5–4.6	183
Aug. 15,	1974	26.9	1.5–6.7	—
Nov. 28,	1974	45.0	2.1–4.9	a few
Oct. 21,	1976	29.2	2.4–4.9	—
May 13,	1977	33.9	—	—
Dec. 10,	1981	26.9	1.8	2
Oct. 15,	1983	26.9	—	—
Nov. 9,	1983	33.9	1.5	—
June 3,	1984	24.7	—	—
May 25,	1985	42.8	3.0–4.6	11,069
Nov. 29,	1988	45.0	1.5–3.0	2,000
April 29,	1991	62.5	6.1–7.6	138,000
June 2,	1991	27.8	1.8	—

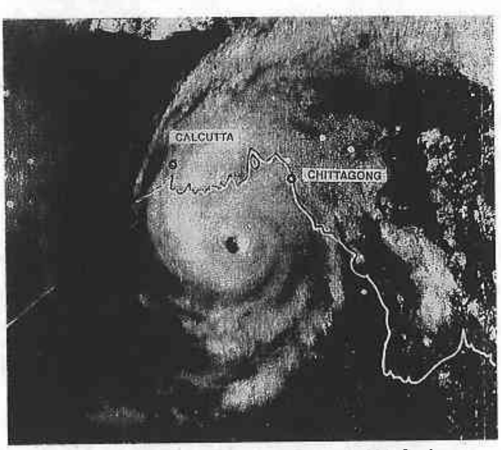

Fig. 3 Satellite Imagery of 29 April 1991 Cyclone (Source: Kar 1991-Ref. 19).

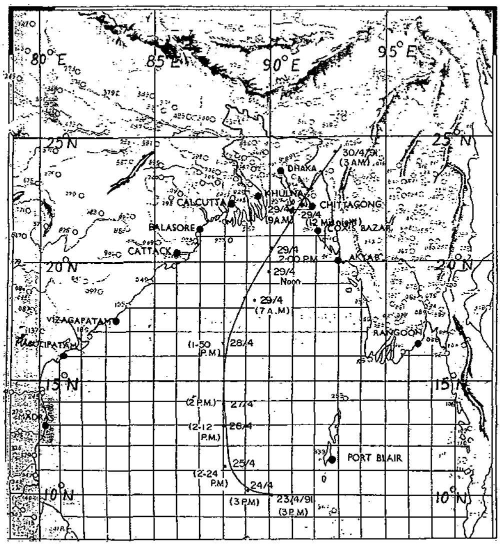

Fig. 4 Track of cyclone (23–30 April 1991).
(Source: SPARRSO 1991–Ref. 18).

poor housing structure and haphazard and clustered settlement pattern, inadequate recovery and response strategy from onslaught of disasters, weak industrial base, maximum dependence on agricultural practices, insufficient transport, communication and other infrastructure facilities. In addition newly emerged islands which are fertile and productive but not yet fit for human habitation are inhabited by people for life struggle of survival and existence. These people are more vulnerable to disasters, particularly cyclonic storms. These newly accrued islands should be consolidated and stabilized through both natural and artificial techniques like massive afforestation and cross-dams. Until stabilized, these islands should not be inhabited by people. Alternate income generating projects (cottage industries, handicrafts, agro-fisheries, tree plantation, etc.) may be initiated in phases at non-vulnerable areas so that these people could avoid living in the vulnerable and hazardous regions, particularly in the newly emerged islands and highly flood-prone areas. This needs long-term strategic planning taking into account the population dynamics and available and potential job opportunities in the country. This is really a gigantic task for a country like Bangladesh with its weak economic base. This calls for international cooperation and massive financial support from donor agencies both on bilateral and multi-lateral basis.

Experiences and lessons learnt from the past disasters are of many folds. The most important one is the participation of the people and the involvement of community based organizations. In Bangladesh there are about 20,000 volunteers in the coastal belt who render valuable services during cyclones. People's participation and helping attitude to one another during floods have been noticed in the past, particularly in 1987 and 1988 floods. This concept and working mechanism need to be strengthened and reinforced throughout the country. In addition there were enormous amount of unquantifiable environmental degradation and ecological imbalances during any disaster. This needs an extensive and in-depth study immediately after the disaster.

The occurrences of severe cyclones and devastating floods are inevitable and are the ferocity and vagaries of nature. These cannot be stopped - but preparedness and appropriate mitigation techniques could help a lot in terms of reducing loss of life, physical property and infrastructure facility. It is felt that believing in the philosophy of "Live with disasters", the following important disaster mitigation tools should be developed:

- Improved forecasting and monitoring techniques.
- Identification of high risk regions and dissemination of information to general public.
- Awareness about disasters to policy makers and others through mass-media.
- Preventive measures - short-term and long-term basis and structural and non-structural methods—as appropriate.

It is also felt that concerted national efforts as well as international cooperation are required for development and implementation of the disaster-mitigation tools and associated activities needed for the purpose. Major sectors/topics to be investigated and developed are - coastal embankments and related structures, bridges, culverts and roads, cyclone shelters, industry and environment, telecommunications, power systems, housing and building, water supply and sanitation, energy, ports and navigation, etc. An integrated approach is needed to attain environmentally sound and sustainable development. It should take into account the effects of disasters in the development process itself with quick recovery and response strategy built-in for the overall mechanism.

5. INCEDE's Goals and Roles in Disaster Mitigation

Within the framework of the broad objectives of INCEDE joint research projects of mutual interest between INCEDE and the concerned agencies of Bangladesh could be undertaken. The possible agencies could be as follows: Bangladesh University of Engineering and Technology (BUET), Cyclone Preparedness Program (CPP), BWDB, BMD, SPARRSO and DOE.

The possible research topics could be as follows:

- Exchange of Japanese and Bangladeshi experiences in windstorms disasters (typhoons/cyclones).
- Studies on water resources, flood damage assessment and flood action plan and their associated environmental factors.
- Evaluation of environmental impacts of some of the completed projects of BWDB such as the Brahmaputra Right Bank Embankment and Coastal Embankment projects.
- Studies on disaster-mitigation techniques including coastal afforestation and cyclone shelters, etc.
- Applications of RS-GIS for disaster monitoring and prediction.
- Organization of training courses, seminars, conferences, workshops on disaster related disciplines.

These research topics/activities could be well-defined and sharply focused and project proposal could be prepared in consultation with the agencies listed above. The mode of operation and funding arrangement of the joint research projects could be initiated through Bangladesh government, Japanese government, donor agencies like UNDP, World Bank and Asian Development Bank.

(Manuscript received, December 28, 1992)

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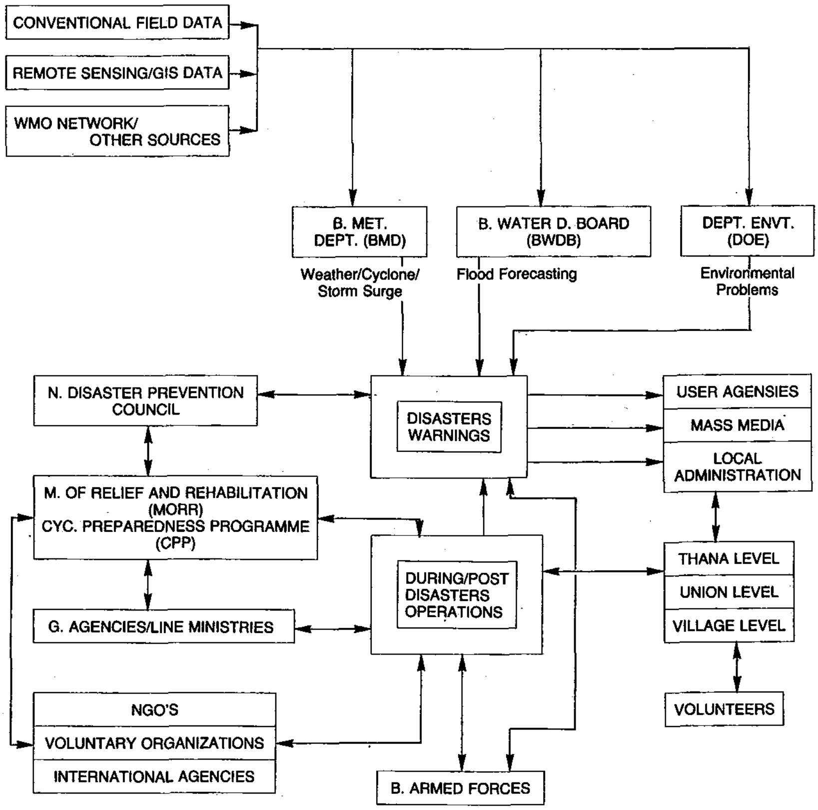
Appendix–A



Disaster forecasting and warning system in Bangladesh