CHAPTER-ONE

1. OVERVIEW OF HYDRO-CLIMATIC HAZARDS

1.1 Introduction

Hydro-climatic disasters are responsible for the serious disruption of the functioning of a society or community and widespread human, material or environmental losses. These disasters and the communities exposed to them may be expected to climb with increased climate variability as a result of climate change. Tragically, the span of attention given to hydro-climatic disastersis often short, probably because the disaster events continue only for a short while, and as the memory of disaster events fades, so does the urgency for disaster risk reduction strategies.

Overview of hydro-climatic hazards (floods, drought, thunderstorms, wind gusts, tidal waves, 0s, hurricanes, tornados, frost and heat waves; El Nino events).

A ***hazard*** is a dangerous phenomenon, substance, human activity or condition that may cause the loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Types of Hazards

Hazards can be associated with **two** types of **events:** ***ongoing and rapid/sudden-onset threats and slowonset (or "creeping") threats.***

1. Ongoing and Rapid/sudden-onset***:*** These would include such hazards as: accidental oil spills, nuclear plant failures, and chemical plant accidents — such as inadvertent chemical releases to the air or into rivers and water bodies ☐ geological hazards and hydro-meteorological hazards (except droughts).

2. ***Slow-onset (or "creeping"):*** Incremental but long-term and cumulative environmental changes that usually receive little attention in their early phases but which, over time, may cause serious crises. These would include such issues as: air and water quality, soil pollution, acid rain, climate change, desertification processes (including soil erosion and land degradation), droughts.

Natural disasters caused by weather include tropical cyclones (hurricanes), tornadoes, floods, heat waves, and droughts. *The causes of floods and flood hazards are a complex mixture of meteorological, hydrological and human factors*. It must be emphasized that human exposure to flood hazards is largely the result of people working and living in areas that are naturally — albeit rarely — subject to flooding.

- In general hydro-climatic hazards can be divided in to three parts

I. Meteorological Hazards: Cyclones, Floods, Tornadoes, Heat, hurricanes, drought

II. Geological Hazards: Tsunamis, Volcanoes, Earthquakes

III. Technological Hazard: A hazard originating from technological or industrial conditions, including accidents, dangerous procedures, infrastructure failures or specific human activities, that may cause loss of life, injury, illness or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

I. Meteorological Hazards

A. Floods are a very common type of natural disaster, and they cause substantial amounts of property damage, and substantial losses of life. While there seems to be limited potential for a flood warning system to produce significant benefits with respect to property damage from floods, the large numbers of lives that are being saved by flood warning systems is quite likely large, and could be larger with further education of the public.

B. Droughts are different from other natural disasters in several respects. In the developed world they rarely claim lives, since wealthy countries have the financial ability to replace food production lost due to droughts. In years past, they have been among the most deadly of hazards in less developed countries, though this may be less true now and into the future as LDC's have become wealthier and international aid responses have developed and become more effective. In terms of property damage, however, droughts are among the most costly of natural hazards. In addition, they are difficult to predict, since they are inherently long-term weather events lasting months or years, and predicting weather over these kinds of time spans is harder than predicting weather over the next few to several days.

C. Tropical cyclones, or hurricanes, as they are called in the United States, are large storm which form over warm ocean waters in the tropics or sub-tropics. They tend to occur seasonally for example, Atlantic hurricanes affecting the United States are concentrated in late summer and early fall. Hurricane damage occurs as a result of powerful winds, flooding (from coastal storm surge and heavy rainfall), and tornadoes that may be spawned by the hurricane.

D. A *tornado* is a column of rapidly rotating air that develops within a thunderstorm. Compared to hurricanes, which can be hundreds of miles wide, tornadoes are much smaller, with a width ranging from less than 100 meters to about a mile.

E. Heat waves are a relatively underappreciated natural disaster. A “heat wave” may be defined as a period of time when temperature and humidity conditions change relatively quickly in ways that present a risk to human health. Heat waves never causes property damage, and they may create only minor discomfort for healthy and relatively well-to-do people who live, work, and drive in air-conditioned spaces.

I. Geological Hazards

A. Earthquakes are movements of the ground that are believed to occur as a result of the earth’s tectonic plates suddenly sliding with respect to each other.

B. Tsunamis are huge ocean waves, potentially exceeding 30 meters in height when they reach land. They are most often generated by earthquakes, though not all earthquakes create tsunamis.

Natural hazards are hazards which are caused **because of natural phenomena** (hazards with meteorological, geological or even biological origin). Examples of natural hazards are cyclones, tsunamis, earthquake and volcanic eruption which are exclusively of natural origin. Landslides, floods, drought, fires are socio-natural hazards since their causes are both natural and manmade. For example flooding may be caused because of heavy rains, landslide or blocking of drains with human waste.

Manmade hazards are hazards which are due to **human negligence.** Manmade hazards are associated with industries or energy generation facilities and include explosions, leakage of toxic waste, pollution, dam failure, wars or civil strife etc. The list of hazards is very long. Many occur frequently while others take place occasionally. However, on the basis of their genesis, they can be categorized as follows:

Table: Various Types of Hazards

Types	Hazards	
Geological Hazards	1. Earthquake 2. Tsunami 3. Volcanic eruption	4. Landslide 5. Dam burst 6. Mine Fire
Water & Climatic Hazards	1. Tropical Cyclone 2. Tornado and Hurricane 3. Floods 4. Drought 5. Hailstorm	6. Cloudburst 7. Landslide 8. Heat & Cold wave 9. Snow Avalanche 10. Sea erosion
Environmental Hazards Biological	1. Environmental pollutions 2. Deforestation 1. Human / Animal Epidemics 2. Pest attacks	3. Desertification 4. Pest Infection 3. Food poisoning 4. Weapons of Mass Destruction

1.2 Social, economic and environmental impacts

Extreme floods have serious social and economic impacts. The most important consequence of flood is the loss of life and property. Structures like houses, bridges; roads etc. get damaged by the gushing water, landslides triggered on account of water getting saturated, boats and fishing nets get damaged. There is huge loss to life and livestock caused by drowning. Lack of proper drinking water facilities, contamination of water (well, ground water, piped water supply) leads to outbreak of epidemics, diarrhea, viral infection, malaria and many other infectious diseases.

Flooding also leads to a large area of agricultural land getting inundated as a result there is a huge crop loss. This results in shortage of food, and animal fodder. Floods may also affect the soil characteristics. The land may be rendered infertile due to erosion of top layer or may turn saline if sea water floods the area.

Urban floods have large impacts particularly in terms of economic losses both direct and indirect. Flood risks are a function of exposure of the people and the economic activities along with the vulnerability of social and economic fabric. As such the impact of such floods on the lives and livelihoods of people, a function of their vulnerability, needs to be understood.

1.3 Benefits and costs of early warning and preparedness

1.3.1 Factors that determine the benefits of early warning systems

Warning systems provide information about possible future natural hazards, or natural disasters, which may threaten injury or loss of life and damage to property.

There are **six** factors that determine **the gross benefits of a warning system**.

The **first tw**o of these relate to **the nature of the natural hazard** itself:

(1) ***Frequency*** – is the natural hazard common or rare?

(2) ***Severity*** – what is the magnitude of the risk to life or the damage to property that the hazard could cause?

If a particular kind of natural hazard occurs relatively frequently, and if the warning system works, there will simply be more opportunities for that system to produce its benefits. And, if the typical severity of that kind of natural hazard is greater, the benefits of a successful warning and response are likely (but not certain) to be greater. A special challenge arises when a kind of hazard is extremely severe but very infrequent, e.g. tsunamis. In these situations, it may be difficult to sustain support for a viable warning system, and to sustain the public's readiness to respond to a warning, over the long periods between recurrences of these events.

Four additional factors jointly determine the most appropriate response when a disaster warning is issued:

(3) ***Lead-time*** – given when the warning is issued, what responses are possible?

Lead-time between a warning and the actual occurrence of a disaster essentially determines the range of responses that one could take – more lead-time generally means that there is a wider range of possible responses to a disaster warning.

(4) Accuracy – is the warning correct?

If the warning is not very accurate, little or no response may be appropriate. On the other hand, if the warning is highly accurate, it will be rational for people to make significant and possibly costly changes in behavior.

(5) Response Costs **–** what are the costs of possible responses to the warning?

The possible responses to a disaster warning will have different costs. Relatively low cost responses are more likely to make sense than relatively high cost responses. High cost responses will make sense only when the potential disaster is severe, the warning is accurate, and the response makes a real difference.

An example of a low cost response is moving to the southwest corner of a basement when there is a tornado warning. Because lead-times for tornado warnings are just minutes, this is about the only response action that makes sense, but it is not costly. An example of a high cost response is large scale coastal evacuation in advance of a possible hurricane landfall. Depending on the population density of the threatened coastline, the cost of evacuation could be in the range of $10 million per mile of coast evacuated.

(6) Loss Reduction -- how much are the expected costs of the disaster reduced, given the likely public response to the warning?

The loss reduction depends on the intrinsic effectiveness of possible actions that may be taken in advance of the natural disaster, as well as the anticipated degree or extent of public response to the warning.

Often the most difficult issue in assessing the likely benefits from an early warning system is predicting the actual public response that will be forthcoming when a disaster warning is issued. Ideally, one would hope that the public response to a disaster warning would be a rational expected cost minimizing response that takes into account forecast lead-time, forecast accuracy, response costs, and loss reductions. However, such rationality is difficult to achieve. Natural disasters typically threaten large numbers of people who are ordinary people not trained in the process of making optimal decisions under uncertainty, and who are almost certainly unaware of the systematic biases that plague decision-making about uncertain events, even for people with a sophisticated understanding of such decision-making. In fact, it is often amajor challenge, both in planning an actual response to a warning, and in estimating the benefits of a warning, to determine what response is optimal, and how closely the actual response can be expected to approximate the optimal one.

When the people at risk from a forecasted hazard are not up to the task of making their own good decisions (e.g. whether to evacuate a coastal area threatened by a hurricane), the success of a warning system will depend importantly on how public authorities manage the response to the threatened disaster. In some countries where there is a high degree of state control over citizens, and it may be fairly easy to command an optimal response from the people threatened by a natural hazard. More often, however, the public response will be voluntary, and the tools available to public authorities will be limited to communication and persuasion as means to induce people to make a rational response to a natural disaster warning. Failure to achieve a rational public response to a disaster warning can mean that the hoped-for benefits of the warning system will be substantially or wholly unrealized.

Finally, the net economic benefit of an early warning system for natural disasters also depends on a seventh factor.

(7) Early Warning System Cost

Obviously, if this cost is low relative to the gross benefits of the warning system, the net benefits of the system will be large, and conversely.

Many of the natural hazards that pose serious threats are meteorological, e.g. cyclones, floods, heat, tornadoes. Forecasts for hazards of this nature are produced jointly by the same weather forecasting system that also produces everyday weather forecasts of general use to the population; that system may need some upgrades to be able to forecast a particular hazard, but a substantial fraction of the system components needed for such forecasting are already in place. This has two implications. First, there is ambiguity about how much of the cost of a weather forecasting system should be attributed to forecasting a particular hazard, e.g. cyclones. Second, forecasts for meteorological hazards are joint products, and the cost of producing forecasts for all such hazards is nearly the same as the cost of producing a forecast for any single one of them. This means that it will make economic sense to produce forecasts for all the meteorological hazards if it makes sense to produce a forecast for any one of them.

Many factors determine the benefits of early warnings systems for the various natural hazards. To develop a subjective scoring system, we first observe that, in order for the benefits of an early warning system to be high, a natural hazard must simultaneously satisfy several criteria: it must be frequent, severe, predictable with reasonable lead-time and accuracy, and there must exist cost-effective responses to warnings of an impending occurrence. If any one of these criteria is not met, the potential benefits from a warning system may be small or even zero. For example, if the hazard is not predictable, it does not matter how frequent, severe, or cost-effective responses to warnings might be --- if one cannot predict the hazard, the benefits of an early warning system will be zero.

1.4 Disaster preparedness

Involves forecasting and taking precautionary measures prior to an imminent threat when advance warnings are possible. Preparedness planning improves the response to the effects of a disaster by organizing the delivery of timely and effective rescue, relief and assistance.

Preparedness involves the development and regular testing of warning systems (linked to forecasting systems) and plans for evacuation or other measures to be taken during a disaster alert period to minimize potential loss of life and physical damage. It also involves the education and training of officials and the population at risk, the training of intervention teams, and the establishment of policies, standards, organizational arrangements and operational plans to be applied following a disaster.

Disaster preparedness minimizes the adverse effects of a hazard through effective precautionary actions, rehabilitation and recovery to ensure the timely, appropriate and effective organization and delivery of relief and assistance following disaster. A coordinated disaster preparedness and response system is an essential condition of any disaster preparedness plan. There is no standard way of ensuring effective coordination. Each design will depend upon the traditions and governmental structure of the country under review. However, a plan will rapidly deteriorate unless there is “horizontal coordination” at central government and sub-national levels among ministries and specialized agencies and “vertical coordination” between central and local authorities.

Chapter-two

2. Origin and nature of hydro-climatic hazards

Floods can be such devastating disasters that anyone can be affected at almost any time. As we have seen, when water falls on the surface of the Earth, it has to go somewhere. In order to reduce the risk due to floods, three main approaches are taken to flood prediction. Statistical studies can be undertaken to attempt to determine the probability and frequency of high discharges of streams that cause flooding. Floods can be modeled and maps can be made to determine the extent of possible flooding when it occurs in the future. And, since the main causes of flooding are abnormal amounts of rainfall and sudden thawing of snow or ice, storms and snow levels can be monitored to provide short-term flood prediction.

Floods result from meteorological and hydrological extremes

The meteorological factors are Rainfall, Cyclonic storms, Small-scale storms, Temperature, Snowfall and snowmelt. The human factors are Land-use changes

2.1 Meteorological regimes

The meteorological causes of floods may be grouped into **four** broad categories:

(a) Small-scale rainstorms causing flash floods;

(b) Widespread storms causing flooding on a regional scale;

(c) Conditions leading to snowmelt; and

(d) Floods resulting from ice jams.

There is a general correlation among storm duration, storm areal extent, the size of the watershed associated with the flood, the duration of flooding, and the time from the beginning of the storm to the flood peak.

Assessment of meteorological hazards should invariably go through the following steps.

(*a*) Forecasting and warning needs

— *Location of area at risk*

— *Type of forecast or warning*

— *Required lead time*

— *Required accuracy;*

(*b*) Data collection

— *Number of satellite pictures available*

— *Availability of other types of data such as synoptic, aircraft-reconnaissance flight reports*

— *Manner and timeliness of reception;*

(*c*) Processing and analysis of data

(*d*) Transmission of data

— *Availability and types of transmission system*

— *Reliability*

— *Timeliness;*

(*e*) Accuracy of forecast and warning

2.2 Hydrological regimes

Several hydrological processes can lead to flooding, and several factors can affect the flood potential of a particular rainstorm or snowmelt event. Some of factors that affect the volume of runoff include:

(a) Soil moisture levels prior to the storm;

(b) Level of shallow groundwater prior to the storm;

(c) Surface infiltration rate: affected by vegetation; soil texture, density and structure; soil moisture; ground litter; and the presence of frozen soil; and

(d) The presence of impervious cover and whether runoff from the impervious cover directly drains into the stream or sewer network;

2.3 Modeling extreme events

2.4 Physical Characteristics of floods

The following characteristics are important in terms of the physical hazard posed by a particular flood:

(a) The depth of water and its spatial variability;

(b) The areal extent of inundation, and in particular the area that is not normally covered with water;

(c) The water velocity and its spatial variability;

(d) Duration of flooding;

(e) Suddenness of onset of flooding; and

(f) Capacity for erosion and sedimentation.

The importance of water velocity should not be underestimated, as high velocity water can be extremely dangerous and destructive. In the case of a flood flowing into a reservoir, the flood volume and possibly hydrograph shape should be added to the list of important characteristics.

2.5 Measurement techniques

In order to understand the characteristics and limitations of flood data, it is helpful to understand measurement techniques (WMO, 1980). Stream flow rates can be measured directly (discharge measurement) or indirectly (stage measurement or slope-area measurement).Direct measurements can be taken by lowering a device into the water that measures water depth and velocity. These are measured repeatedly along a line perpendicular to the direction of flow. For any reasonably sized river a bridge, cableway or boat is necessary for discharge measurement. Discharge (m3/s) through each cross-section is calculated as the product of the velocity and the cross-sectional flow area. Most gauging stations are located such that there is a unique or approximately unique relation between flow rate, velocity and stage. The flow-rate measurements may, therefore, be plotted against stage measurements to produce a rating curve. Once the rating curve is established, continuous or periodic stage measurements made either automatically or manually, can be converted to estimates of discharge. Because measurements of discharge during floods are difficult to make when the water levels and flow velocities are high, it is common to have records of only stage measurement during major floods.

2.6 Frequency of Flooding

Flood frequencies can be determined for any given stream if data is available for discharge of the stream over an extended period of time. Such data allows statistical analysis to determine how often a given discharge or stage of a river is expected. From this analysis a recurrence interval can be determined and a probability calculated for the likelihood of a given discharge in the stream for any year. The data needed to perform this analysis are the yearly maximum discharge of a stream from one gauging station over a long enough period of time.

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- In order to **determine the recurrence interval**, the yearly discharge values are first ranked. Each discharge is associated with **a rank, m**, with m = 1 given to the maximum discharge over the years of record, m = 2 given to the second highest discharge, m = 3 given to the third highest discharge, etc.

- The smallest discharge will receive a rank equal to the number of years over which there is a **record, n**. Thus, the discharge with the smallest value will **have m = n**.
- The number of years of record, n, and the rank for each peak discharge are then used to calculate recurrence interval, **R** by the following equation, called the Weibull equation:

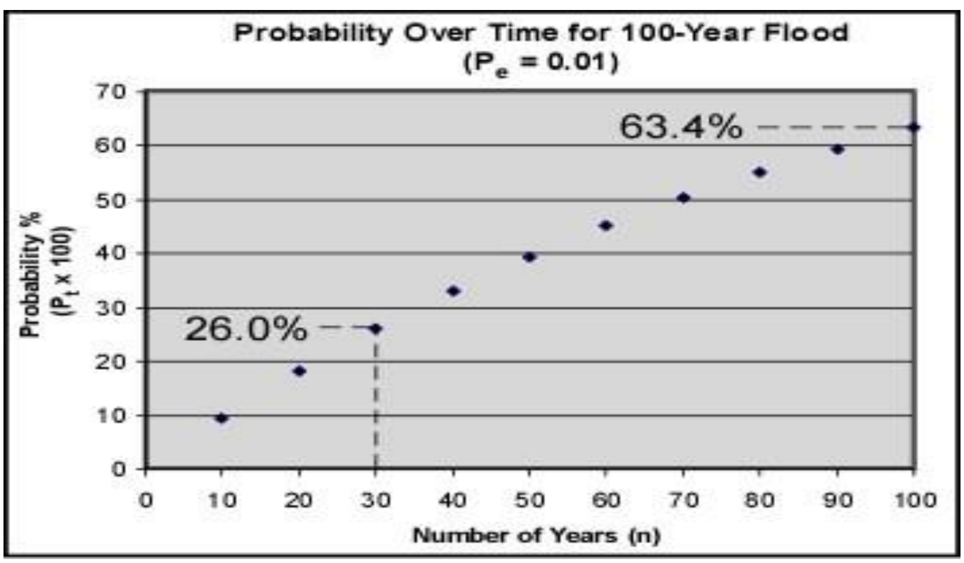
$$\mathbf{R = (n+1)/m}$$

- The probability, **Pe,** of a certain discharge can be calculated using the inverse of the Weibull equation:

$$\mathbf{Pe = m/(n+1)}$$

- The value, Pe, is called the annual exceedence probability.

For example, a discharge equal to that of a 10-year flood would have an annual exceedence probability of 1/10 = 0.1 or 10%. This would say that in any given year, the probability that a flood with a discharge equal to or greater than that of a 10 year flood would be 0.1 or 10%. Similarly, the probability of a flood with discharge exceeding the 100 year flood in any given year would be 1/100 = 0.01, or 1%.



CHAPTER-THREE

3. MANAGEMENT AND MITIGATION OF HAZARDS/DISASTERS

Floods can be managed through structural interventions such as dikes, barrages, diversion canals, dams and reservoirs. Non-structural measures such as flood forecasting, public awareness and early warning system would be part of the management process.

Disaster Risk Management includes sum total of all activities, programmes and measures which can be taken up before, during and after a disaster with the purpose to avoid a disaster, reduce its impact or recover from its losses.

The **three key stages of activit**ies that are taken up within disaster risk management are:

A) Before a disaster (pre-disaster)

Activities taken to reduce human and property losses caused by a potential hazard. For example carrying out awareness campaigns, strengthening the existing weak structures, preparation of the disaster management plans at household and community level etc. Such risk reduction measures taken under this stage are termed as mitigation and preparedness activities.

B) **During a disaster (disaster occurrence**)

Initiatives taken to ensure that the needs and provisions of victims are met and suffering is minimized. Activities taken under this stage are called emergency response activities.

C) After a disaster (post-disaster***)***

Initiatives taken in response to a disaster with a purpose to achieve early recovery and rehabilitation of affected communities, immediately after a disaster strikes. These are called as response and recovery activities.

Mitigation of flood hazards can be attempted in two main ways: An engineering approach, to control flooding, and a regulatory approach designed to decrease vulnerability to flooding.

Mitigation embraces measures taken to reduce both the effect of the hazard and the vulnerable conditions to it in order to reduce the scale of a future disaster. Therefore mitigation activities can be focused on the hazard itself or the elements exposed to the threat. Examples of mitigation measures which are hazard specific include water management in drought prone areas, relocating people away from the hazard prone areas and by strengthening structures to reduce damage when a hazard occurs. In addition to these physical measures, mitigation should also aim at reducing the economic and social vulnerabilities of potential disasters.

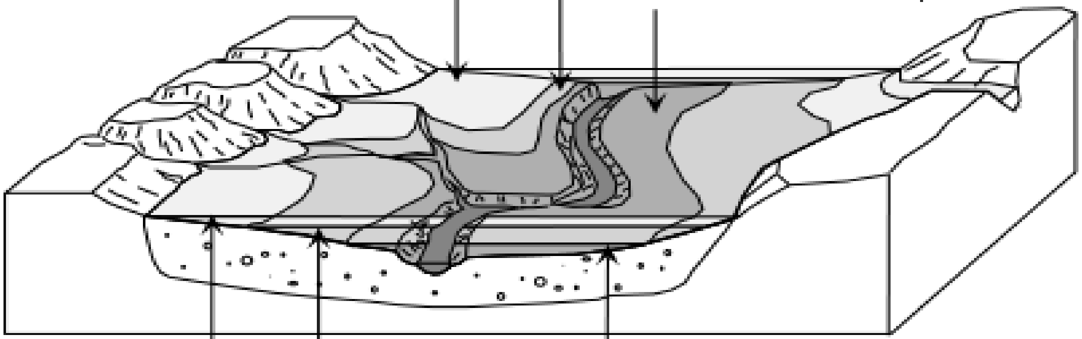
3.1 Hazard Maps, Risk Information and Education

Food hazard mapping is used to determine the areas susceptible to flooding when discharge of a stream exceeds the bank-full stage. Using historical data on river stages and discharge of previous floods, along with topographic data, maps can be constructed to show areas expected to be covered with floodwaters for various discharges or stages.

Communication is critical during an emergency and needs to be addressed thoroughly within the disaster-response plan. Successful disaster response plans requires information and mobilisation response teams, provide guidance, instructions to the affected people, and communicate with the appropriate authorities and external stakeholders

Challenges include reaching people in different locations quickly and simultaneously; providing the right message (in terms of content, length, and format); monitoring delivery and response; and ensuring that the process is initiated and suspended at the right times.

Mapping is a central tool in communicating hazard identification and assessment. Maps can accurately record the location, probable severity and likelihood of occurrence of hazards and display this information clearly and conveniently. It may be based on a range of data sources e.g. existing maps, remote sensing, surveying. Additional information from photography, field surveys and other sources can be overlaid onto base maps. Geographical Information Systems (GIS) are making this much easier. Community hazard mapping exercises can also be undertaken. Communities are often knowledgeable about the location and nature of local hazards and their causal factors. Such information is particularly valuable in identifying and appraising localised hazards but community level outputs can also feed into Community hazard mapping exercises can also be undertaken. Communities are often knowledgeable about the location and nature of local hazards and their causal factors. Such information is particularly valuable in identifying and appraising localised hazards but community level outputs can also feed into higher level mapping and planning. Maps are a good medium for communicating hazard information to decision-makers and non-specialists, but then the particular formats and symbols should be kept familiar.



In constructing such maps aerial photographs and satellite images of prior floods are studied to help to determine the areas that would be covered. The illustration above shows a possible hazard map based on estimated discharges or river stages for a hypothetical 10-year flood, 50-year flood, and 100-year flood.

3.2 Possible Flood Risk Reduction Measures

- Mapping of the flood prone areas

It is the primary step involved in reducing the risk of the region. Historical records give the indication of the flood inundation areas and the period of occurrence and the extent of the coverage. Warning can be issued looking into the earlier marked heights of the water levels in case of potential threat. In the coastal areas the tide levels and the land characteristics will determine the submergence areas. Flood hazard mapping will give the proper indication of water flow during floods.

- ***Land use control***

It will reduce danger of life and property when waters inundate the floodplains and the coastal areas. The number of casualties is related to the population in the area at risk. In areas where people already have built their settlements, measures should be taken to relocate to better sites so as to reduce vulnerability. No major development should be permitted in the areas which are subjected to high flooding. Important facilities like hospitals, schools should be built in safe areas. In urban areas, water holding areas can be created like ponds, lakes or low-lying areas.

- ***Construction of engineered structures***

In the flood plains and strengthening of structures to withstand flood forces and seepage. The buildings should be constructed on an elevated area. If necessary build on stilts or platform.

- ***Flood Control***

Aims to reduce flood damage. This can be done by decreasing the amount of runoff with the help of reforestation (to increase absorption could be a mitigation strategy in certain areas),protection of vegetation, clearing of debris from streams and other water holding areas, conservation of ponds and lakes etc. Flood Diversion include **levees, embankments**, **dam**s and **channel improvement**. Dams can store water and can release water at a manageable rate. But failure of dams in earthquakes and operation of releasing the water can cause floods in the lower areas.

Flood Proofing reduces the risk of damage. Measures include use of sand bags to keep flood water away, blocking or sealing of doors and windows of houses etc. Houses may be elevated by building on raised land. Buildings should be constructed away from water bodies.

- ***Flood Management***

Flood management can aim at

(i) A reduced risk of floods;

(ii) A reduced vulnerability to floods;

(iii) Improved preparedness;

(iv) Stream lined emergency management once a flood damage has occurred; and

(v) Improved knowledge (about cause-effect relationships, driving forces and management Options);

Good flood management would take its starting point in a suitable knowledge about

(i) The flood risk (so that high-risk areas are delineated); and

(ii) The flood vulnerability (so that the most important potential consequences are Identified).

Different methods of flood protection structural as well as nonstructural have been adopted in different states depending upon the nature of the problem and local conditions. Structural measures include storage reservoirs, flood embankments, drainage channels, erosion works, channel improvement works, detention basins etc. and non-structural measures include flood forecasting, flood plain zoning, flood proofing, disaster Preparedness etc.

Various possible flood hazard mitigation options to manage urban flood risks are summarized below:

- **Reducing local floods by inducing infiltration through:**

  - Preservation of unsealed areas,

  - Preservation of natural ponds,

  - inducing groundwater recharge and greening of unsealed areas,

  - introducing permeable paving's,

  - Provision of infiltration trenches, soak ways etc.

- **Retaining/ transferring local floods:**

  - Minor and major urban drainage system (storm water channels, gutters, culverts, pumps etc.)

  - preventing clogging of drainage facilities (cleaning, dredging, solid waste collection etc.)

  - Detention and retention basins

  - Rainwater harvesting

- **Preventing storm water contamination:**

  - Strict separation of sewage and storm water drainage

  -protect potential contamination sources (sewage plants, landfills, patrol stations etc.) against floods

3.3 Strategic approach: structural measures

Prevention and preparedness approaches are:

Structural measures: Infrastructure, environmental shield, retrofitting

Nonstructural measures: Poverty alleviation, empowerment of disadvantaged groups, capacity building, risk transfer, insurance

Among these **non-structural measures** are:

- Floodplain zoning - Laws can be passed that restrict construction and habitation of floodplains. Instead floodplains can be zoned for agricultural use, recreation, or other uses wherein lives and property are not endangered when flood waters re-occupy the floodplain.
- Floodplain building codes - Structures that are allowed within the floodplain could be restricted those that can withstand the high velocity of flood waters and are high enough off the ground to reduce risk of contact with water.
- Floodplain buyout programs - In areas that have been recently flooded, it may be more cost effective for the government, which usually pays for flood damage either through subsidized flood insurance or direct disaster relief, to buy the rights to the land rather than pay the cost of reconstruction and then have to pay again the next time the river floods.

- Mortgage limitations - Lending institutions could refuse to give loans to buy or construct dwellings or businesses in flood prone areas.

3.4 Early warning

Early warning systems are often described in terms of the detection, warning dissemination, response, recovery and review stages. In many cases, a forecasting component will also be included, and preparedness is essential for an effective emergency response. This structure is also adopted here, although with only a short discussion of the recovery phase, since flood warning and forecasting has a less important role to play once flood levels start to recede, such as estimating when floodwaters will drain, or if any further flooding is imminent. By contrast, the warning aspect is discussed in several locations, including a chapter on the decision criteria used for issuing flood warnings (often called thresholds) and sections on decision support and decision-making under uncertainty.

Early warning systems help to reduce economic losses and mitigate the number of injuries or deaths from a disaster, by providing information that allows individuals and communities to protect their lives and property. Early warning information empowers people to take action when a disaster closes to happening. If well integrated with risk assessment studies and communication and action plans, early warning systems can lead to substantive benefits.

There are three main sections in flood warning systems:

Part I**.** Flood Warning- which discusses the topics of detection, thresholds and dissemination

Part II. Flood Forecasting- which discusses general principles, specific types of river and coastal forecasting models, and examples of specific applications

Part III**.** Emergency Response- which covers the topic of preparedness, response and review

3.4.1 The Flood Warning Process

Flood warning systems provide a well-established way to help to reduce risk to life, and to allow communities and the emergency services time to prepare for flooding and to protect possessions and property. Actions may also be taken to reduce or prevent flooding; for example, by operating river control structures, and flood fighting activities such as reinforcing flood defences, and installing temporary or demountable barriers.

Informal flood warning systems have existed ever since people started to live and worknear rivers and coastlines. Heavy rainfall, high river levels, unusual sea states and other cues, such as the sound of running water, all provide useful information on impending flooding, with traditional methods for providing warnings including word of mouth, messengers, and raising flags and storm cones.

These approaches still have a valuable role to play, particularly where flooding develops rapidly, and communities must rely on their own resources for the initial response. A flood warning system can include rainfall and tidal detection systems, river and coastal flood forecasting models, flood warning dissemination systems, and emergency response procedures.

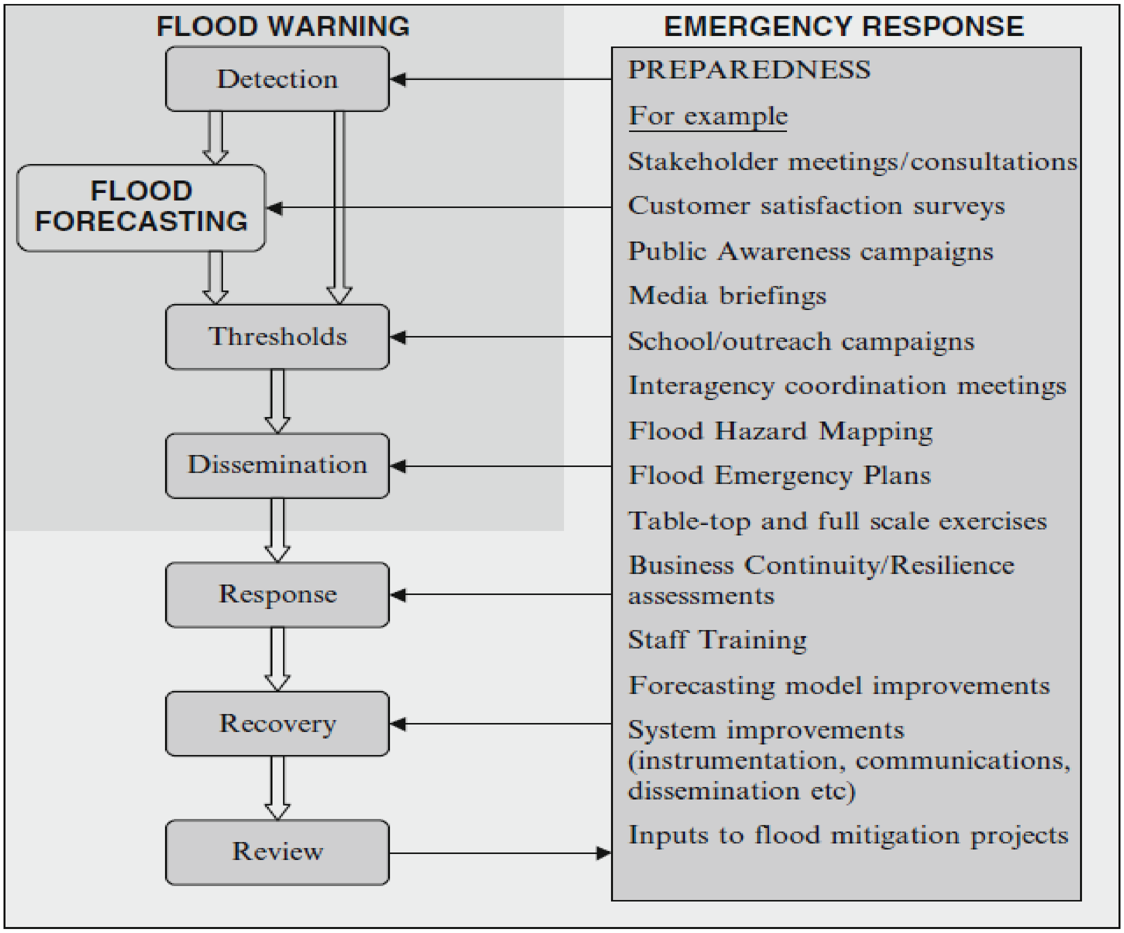


Fig. Illustration of the components of a flood warning, forecasting and emergency response system

Table: Typical components in the flood warning, forecasting and emergency response process

Item	Component	Examples
Flood warning	Detection	Monitoring of meteorological, river and tidal conditions; and meteorological forecasting (e.g. nowcasting, numerical weather prediction)
	Thresholds	The meteorological, river and coastal conditions under which decisions are taken to issue flood warnings (sometimes called triggers, criteria, warning levels or alarms)
	Dissemination	Procedures and techniques for issuing warnings to the public, local authorities, emergency services, and others
Flood forecasting	Rivers, coasts	Conceptual, data based and process based models for forecasting future river and coastal conditions
Emergency response	Response	Emergency works, temporary barriers, flow control, evacuation, rescue, incident management, decision support
	Recovery	Repairs, debris removal, reuniting families, emergency funding arrangements, providing shelter, food, water, medical care, counselling, support to businesses, restoration of services if interrupted
	Review	Review of the performance of all components of the system, and recommendations for improvements
	Preparedness	Emergency planning, public awareness campaigns, training, systems improvements, business continuity/resilience assessments, flood risk mitigation etc.

The resilience of flood warning systems to failure is also an important consideration, and risk based techniques from other technical sectors and types of emergency are gradually being introduced to help to identify potential points of failure, and appropriate risk reduction measures. There is also much debate about the effectiveness of flood warnings. Clearly, a warning is successful if it initiates action which prevents flooding which might otherwise have occurred in the absence of that warning; for example by triggering the closure of a tidal barrier, or installation of a temporary defense. However, research suggests that success with providing warnings to the public is mixed, although in some countries has improved markedly in recent years through a combination of using flood forecasting models to extend the lead time and accuracy of warnings, a better understanding of how to communicate warnings, and an increased emphasis on Community participation and inter-agency collaboration.

For example, one recommendation (Emergency Management Australia 1999) is that the flood warning task can be boiled down to providing appropriate responses to the following **five questions**:

1. How high will the flood reach, and when?

2. Where will the water go at the predicted height?

3. Who will be affected by the flooding?

4. What information and advice do the people affected by the flooding need to respond effectively?

5. How can the people affected by the flooding best be given the appropriate information?

A particular issue to consider is that of the requirements for warning lead time, which can range from a few minutes or less for people on a steep sloping river bank to reach higher ground, to many hours or days for some situations, such as raising temporary defences, evacuating large numbers of people, or drawing down a reservoir in advance of flooding. Similarly, the requirements for accuracy, and tolerance to false alarms, will vary between organizations and communities, and can be influenced by education and public awareness exercises.

3.4.2 The Nature of Flood Risk

Flooding is a threat to many communities and businesses, and flood risk is increasing in some locations due to development on floodplains, migration to urban areas at risk from flooding, and artificial influences on flow regimes; for example, urban developments can sometimes increase flood risk through changes to runoff characteristics and the drainage paths of floodwater. Climate change may also be increasing the likelihood of flooding in some places through changes in the frequency and severity of storms, patterns of snowfall and snowmelt, and rising sea levels.

Compared to other types of natural disaster, floods account for approximately 20–40% of the events which are reported. Floods can also cause extensive damage to property, infrastructure and crops, and can cut across administrative and national boundaries.

The causes of flooding are mainly atmospheric or geotechnical (as described in the table below).Atmospheric hazards include heavy rainfall, causing rivers to flood, sometimes linked to snowmelt and ice-jams in colder climates, and coastal and estuarine flooding due to surge, wave and wind effects, most notably in tropical cyclones, hurricanes and typhoons. Geotechnical factors such as landslides, debris flows and earthquakes can also lead to raised river levels causing inland flooding, and Tsunami waves resulting in coastal flooding. Secondary effects may include overtopping or breaches of river and sea defense structures, debris blockages at bridges and other structures, surcharging of drainage networks in urban areas, and dam failure or overtopping.

Examples of flooding mechanisms

Type	Example	Typical types of flooding
Atmospheric	Frontal depressions	Extensive river flooding, coastal surge and wave overtopping, estuary and delta flooding, urban and pluvial (surface water) flooding
	Thunderstorms	Fast response/flash flooding and urban and pluvial (surface water) flooding
	Monsoon	Extreme prolonged rainfall causing a range of river and urban flooding issues
	Tropical cyclones	Coastal surge and wave overtopping, inland flooding, estuary and delta flooding
	Snowmelt	Extensive river flooding
	Ice jams	Rapid rises in river levels
	Glacial lake outburst flows	Fast moving, deep river flows
Geotechnical	Dam break	Fast moving, deep river flows
	Defence breach	Extensive inundation of coastal or inland areas
	Tsunami	Extensive inundation of coastal margins
	Debris flow	Destructive flows with high mud and rock content

Due to the short time available for people to react, fast developing floods present a particular risk to life, including flash floods, dam or defense breaches, and some ice-jam and local surge and wave overtopping events. Tropical cyclones, hurricanes and typhoons are all forms of tropical storm, with the term tropical cyclone used in the Indian Ocean, hurricane in the Atlantic and Eastern Pacific Oceans, and typhoon in the Western Pacific. Frontal depressions are most common in mid-latitudes, and can cause prolonged rainfall, as can monsoons which are driven by seasonal variations in temperature between sea and land masses. Thunderstorms can occur at most latitudes, and can cause intense rainfall for periods of typically up to a few hours. Snow and ice related problems affect many high latitude regions on all continents, and high mountain ranges elsewhere. Dam and defense risks are possible anywhere that reservoirs or polders have been constructed, or dams built across lakes, as are breaches in river or coastal flood defences (often known as levees or dikes).

3.4.3 Assessing Flood Risk

Flood risk is often expressed as the combination of **two factors**; **probability (or hazard) and consequence (or impact)**. The probability expresses the likelihood of damaging flood levels or flows being reached, whilst the consequence can be expressed in terms of indicators such as the numbers of properties affected, loss of life, or economic damages.

Risk is a "measure of the expected losses due to a hazard event occurring in a given area over a specific time period. Risk is a function of the probability of particular hazardous event and the losses each would cause."

The level of **risk depends upon:**

- *Nature of the hazard*
- *Vulnerability of the elements which are affected*
- *Economic value of those elements*

Estimates for the numbers of people at risk from flooding, and affected in individual events, are of course subject to many uncertainties, including the degree to which events are reported, the approach taken to flood risk assessments and, for international comparisons, differences in the datasets and recording methods which are used. However, some studies (e.g. Parker 2000; Smith 2004) suggest that the percentages of people at risk from flooding range from 3% to 5% of the population in the UK and France, to about 12% in the USA, 50% in the Netherlands, and 70–80% in Vietnam and Bangladesh. Estimates are also complicated by transient populations, which can include tourists, hikers, temporary workers, business travelers, and the homeless.

The link between flood risk and social, political and economic factors, particularly risk to life, is well documented, and can arise from issues such as a lack of public awareness of flooding issues, or controls on floodplain development, limited funds available for flood control and protection (e.g. river and sea defences), low resilience of buildings to flooding (e.g. temporary compared to permanent settlements), and a lack of investment in flood warning, forecasting and emergency response systems. Where these factors are significant, the numbers of people affected by a flood event can be much higher than equivalent events in locations without these problems.

Measures of vulnerability to flooding are also increasingly considered in flood risk studies: for example, combining the following factors (e.g. Wade et al. 2005):

● Flood hazard (depth, velocity, debris)

● Area Vulnerability (effectiveness of flood warning, speed of onset of flooding, and type of Buildings e.g. low rise/high rise)

● People Vulnerability (ability to ensure own safety and that of dependents e.g. the elderly, infirm, children) Of course, vulnerability to flooding can depend on a wide range of physical, environmental, social, economic, political, cultural and institutional factors, and can vary widely between individuals, households and communities; for example, the length of time that people have lived in the floodplain (or if they are visiting the area e.g. tourists), recent experience of flooding, and local institutional capacity to respond to flooding.

When designing a flood warning scheme, a starting point is often to make an **assessment of the locations and numbers of people and properties at risk from flooding**. Vulnerability studies can also highlight where to target effort in public awareness campaigns, developing flood emergency plans, and in emergency response. Methods for assessing risk include interviews with people who know the area well, examination of historical flood records (trash mark surveys, aerial and other photographs, newspaper reports, satellite images etc.), and hydrodynamic and other modeling techniques.

Risk is the probability of something happening in the future, which has a negative consequence. It is a prediction of suffering harm or loss or of meeting danger. Although disaster risk is sometimes taken as synonymous with hazard, it has an additional implication of likelihood of a particular hazard to occur and cause damage or loss to a vulnerable community or group. Disaster Risk (or recipe for disaster) has been presented by Ward, 1999 as follows:

$$\text{Disaster Risk} = \frac{\text{Hazard x Vulnerability}}{\text{Manageability}}$$

Manageability here stands for the degree to which a community can intervene and manage a hazard in order to reduce its potential impact. This implies that based on people's perception of their disaster risk, they are able to make decisions to adapt to, modify or ignore the risk. Manageability is synonymous to Capacity so we can substitute to have the following disaster risk formula:

$$\text{Disaster Risk} = \frac{\text{Hazard x Vulnerability}}{\text{Capacity}}$$

round survey and remote sensing techniques can also provide detailed maps of flooding extent, although not necessarily for the peak of the flood, and satellite observations are increasingly being used to monitor flood extents using both optical and microwave frequencies, and to build up databases of flood extent information. Models provide a more formal way of assessing flood risk, and can range from simple correlation and other methods for single locations, through to detailed hydraulic models for river and coastal processes.

3.4.4 Flood risk modeling

The national flood risk mapping programmes in many countries use a range of modeling techniques to estimate flood depths, velocities and extents. For rivers, for example, actual or synthetic rainfall events can be fed into a network of rainfall runoff models representing major sub-catchments, whose outputs provide the inputs to a model for the river network and significant features such as floodplains and reservoirs. In areas prone to flooding, the model detail may include all significant controls on river levels and flows, such as bridges, culverts, gates, defences and other features, as well as the main details of the floodplain, using construction and topographic information obtained from conventional survey and remote sensing techniques (e.g. Light Detection and Ranging LIDAR equipment, or Synthetic Aperture Radar SAR equipment). In increasing order of complexity (and, in principle, accuracy), process-based methods for modeling river levels, flows and, in some cases, velocities, on the floodplain can include:

- ***One-dimensional models*** for the **main river channel**, with projection of levels onto the floodplain, or separate pathways for main channel and floodplain flows
- ***One-dimensional models*** including **floodplain** pathways represented via spill units, Compartments and/or cells
- ***Two dimensional models*** of the floodplain using 'bare earth' digital terrain models based on mass conservation only, or including momentum effects as well.
- ***Fully two or three dimensional models*** of the floodplain incorporating features on the floodplain such as buildings, embankments, gulleys etc., and possibly urban drainage networks

Hydrodynamic techniques can also be used for modeling inundation of coastal floodplains due to high tidal levels, wave action and surge. Maps maybe developed either with or without flood defences, with the no defense case sometimes being used to study the worst case flood extent; for example, if defense is breached, overtopped or bypassed.

However, whatever the technique used to assess flood risk, one problem is always to assess the extent of mobile and transient populations who may not appear in conventional property and census databases. Examples can include vehicle users, shopping centers, supermarkets, tourists, hikers, outdoor events, and locations such as caravan or mobile home parks, and camp sites. Local visits, and discussions with people who know the area well, may be the best way of determining the extent of this risk, and the options (if any) for providing warnings to these groups, or preventing access in time to minimize the flood risk.

Some other problems which can arise with property databases are that they may omit some commercial properties with significant numbers of occupants during working hours, since the correspondence address is at another location (e.g. head office), and that some locations with many residents (e.g. apartment blocks) may appear as only a single property. Also, some high-risk locations may not be clearly identified, such as water treatment or industrial works and critical locations such as hospitals, power stations, telecommunications hubs etc. Again, local visits and discussions can help to resolve some of these issues.

3.5 Emergency Response

Emergency response is the process of responding to a flood event, ideally on the basis of a flood warning received. In many countries, there are separation inresponsibilities between the flood warning and forecasting service, and emergency responders such as the police, fire service and local authorities. However, the organization of a flood warning service can vary widely, with warnings being issued by the meteorological service in some countries, and a range of river management, coastal and local authorities in others. Privately developed systems also operate in some locations; with applications ranging from community based warning systems through to systems operated by owners of major infrastructure such as railways and hydropower schemes. Sometimes warnings may also be restricted to specific types of flooding, such as river flooding or coastal flooding, and exclude other types, such as flooding in urban areas from drainage problems.

A major flood event often requires a multi-agency response, involving local authorities, the emergency services, transport operators (road, rail etc.), utility operators (water, electricity, gas, and telecommunications), the military, coastguard, medical services, voluntary services, humanitarian aid organizations, and others.

The response can include closing transport routes, protection of key installations, such as power stations and water treatment works, reinforcing flood defences, providing rest centers and shelters for people evacuated from properties, and rescue of people and livestock stranded in flood waters. Difficult decisions may also need to be made on issues such as the need to evacuate hospitals and nursing homes (with the evacuation itself presenting risks), precautionary shutdown of power or water supplies, and ordering widespread evacuations of property.

During a flood event, individual property owners can also take action to reduce the damage caused by flooding by moving (as appropriate) vehicles, furniture, electrical equipment, personal possessions, valuables, animals and livestock to safer locations, and using sandbags, flood boards and other flood resilience measures to protect their property (if available). For example, in a post event survey of flooding in parts of the Elbe and Danube catchments (Thieken et al. 2007), emergency measures which were reported by residents included:

- *Put moveable contents upstairs*
- *Drive vehicles to a flood-safe place*
- *Safeguard documents and valuables*
- *Protect the building against inflowing water*
- *Switch off gas/electricity*
- *Disconnect household appliances/white goods*
- *Gas/electricity was switched off by public services*
- *Protect oil tanks*
- *Install water pumps*
- *Seal drainage/prevent backwater*
- *Safeguard domestic animals/pets*
- *Redirect water flow*

Businesses can also take actions to reduce damage to stock, equipment and systems and, depending on the time of day, may also be able to advise employees not to come in to work, or to leave early, in order to minimize risk.

There are a vast number of responses that ought to be considered. Each response depends upon the nature of the threat. Some of the broader categories of response for a variety of hazards include:

- *Evacuation procedures*
- *Search and rescue*
- *Security of affected areas*
- *Assessment teams*
- *Activating special installations (such as emergency hospital facilities)*
- *Activating distribution systems*
- *preparing emergency reception centers and shelters*
- *activating emergency programs for airports, harbors and land transport*

Flood warnings can also assist river management and coastal authorities with the operation of structures and in other actions to help to reduce or prevent flooding and some examples include as shown below:

Fig. Examples of river and coastal flood defences and a flood gate for wash land drainage

- Flood barriers – installation or operation of temporary or demountable barriers to protect properties and infrastructure from flooding
- Flood gates – closing gates which at low to medium flows are normally kept open to allow for drainage, access, navigation etc.
- Flow diversion – diversion of river flows into off-line storage areas to reduce flows further downstream (e.g. wetlands, flood retention areas)
- Pumping – use of high volume pumps to reduce water levels Reservoirs – draw down of reservoir levels in advance of high inflows to provide flood storage to reduce flows further downstream
- Sandbags – placing sand bags to raise the level of flood defences, fill gaps in defences, or to protect properties
- Temporary works – emergency repairs to flood defences (levees and dikes) and other locations which might provide a flow route for flood water
- Tidal barriers – closing barriers or gates to reduce the risk of inland flooding due to surge or high tides.

3.6 Flood Emergency Planning

General Principles

Flood Emergency Plans describe the actions to take between, during and following flood events, and typically cover operational procedures, emergency response assets, and contact details for key staff, health and safety issues, procedures for liaison with the media and the public, and information on safe access and evacuation routes and shelters. Some guidelines on developing flood emergency plans include US Army Corps of Engineers (1996), NOAA/NWS (1997) and Emergency Management Australia (1999) for river flooding and Holland (2007) for tropical cyclone forecasting. Depending on the type of flooding, lead time available, and population affected, examples of actions which may need to be taken in the run up to and during a flood event include (USACE 1996):

● *Providing search, rescue, and evacuation services*

● *Scheduling closure of schools and transportation of students*

● *Curtailing electric and gas service to prevent fire and explosions*

Establishing traffic controls to facilitate evacuation and prevent inadvertent travel into hazardous areas

● *Dispersing fire and rescue services for continued protection*

● *Establishing emergency medical services and shelters*

● *Closing levee openings*

● *Moving public and private vehicles and equipment from areas subject to flooding*

● *Relocating or stacking contents of private structures*

● *initiating flood-fighting efforts (e.g. sandbagging etc.)*

● *Establishing security to prevent looting*

3.7 Disaster management

The overall **Goal** of Disaster Management is to build a safe, resilient and sustainable society.

Objectives

- To establish a policy/legal and institutional framework for management of disasters, including promotion of a culture of disaster awareness and for building the capacity for disaster risk reduction, at all levels;
- To ensure that institutions and activities for disaster risk management are coordinated, focused to foster participatory partnerships

- To promote linkages between disaster risk management and sustainable development for reduction of vulnerability to hazards and disasters;
- To ensure proactive management of National Conflict Resolution and Peace Building efforts, which are enhanced continuously throughout the country, within every conflict disaster cycle; and that their consequences and impacts are systematically addressed, monitored, and evaluated to prevent conflict occurrence/recurrence and hasten effective and sustainable recovery of the victims;
- To mobilize resources, including establishment of specific funds for disaster risk reduction strategies and programmers in DM;
- To make institutional provisions to ensure productive networking and sharing of information; and
- To make available sensitization, awareness creation and functional literacy to thepublic for disaster management.

3.8 Evacuation

It is the ultimate measure of flood defence, aiming to save lives and reduce losses. Evacuation can take place before, during after the flood, depending upon the circumstances and is always tightly linked with other measures of flood defense.

All relevant aspects of an evacuation should be planned in advance to reduce last minute decisions to a minimum.

- *Criteria and Timing*
- *Affected area and population*
- *Direction of Evacuation*
- *Preparedness for Evacuation*
- *Warninig and evacuation order*
- *Financial Aspects*
- *Recording and documentation*
- *Adjustment and periodical renewal of plans*

3.9 Information system

Information systems: coordinate means of gathering and disseminating vulnerability assessment and early warning within and between agencies and organizations and with the public. Most floods warning systems use near real time measurements of meteorological and river or coastal conditions to guide operational decision making. Depending on the application, this may include information on rainfall, wind speeds, sea state, tidal levels, river levels and other parameters, such as snow cover. Remote sensing techniques such as weather radar and satellite may also be used, together with the outputs from Numerical Weather Prediction models and now casting techniques.

3.9.1 Meteorological and hydrological forecasting (meteorological and hydrological networks; need for integration)

With only a few exceptions, such as geotechnical risks most flooding problems are linked to atmospheric conditions, and observations or forecasts of rainfall and other parameters often provide the first indication of potential flooding.

The main types of meteorological information which are useful in flood warning and forecasting applications include:

- Site Specific (or Point) Observations – measurements at a specific location using rain gauges, automatic weather stations etc.
- Remote Sensing (or Areal) Observations – based on satellite observations, weather radar etc.
- Computer Model Outputs – from Numerical Weather Prediction (NWP) models, now casting techniques

When considering these approaches, there are various trade-offs in terms of the spatial resolution, accuracy and lead times of each technique. For example, site specific observations provide an indication of actual conditions at certain locations in a catchment or coastal reach, but may be unrepresentative of the overall conditions which lead to flooding. By contrast, remotely sensed data provide an overall picture of the distribution of the parameter being observed (e.g. rainfall, snow cover), but require some assumptions or a model to translate observations to conditions at the ground or sea surface. This introduces an additional source of uncertainty, and measurements are sometimes of too coarse a resolution to be useful.

Weather forecasting techniques provide additional lead times, and usually also provide detailed spatial information for the parameters being forecast (rainfall, wind, soil moisture etc.), but obviously rely on the outputs from computer models, which again can introduce an additional source of uncertainty.

For river flooding applications, rainfall is often a key parameter, although other meteorological parameters which may be required include observations or estimates for air temperature, wind speed, net and solar radiation, soil moisture, snow cover, river ice cover and ice jam locations, and reservoir and lake evaporation. For coastal flooding applications, information on atmospheric pressure, and wind speed and direction, is often a key input to surge and wave forecasting models and, for tropical cyclones (and hurricanes and typhoons), information on storm size, intensity, track and speed is also important.

If factors such as amount of rainfall, degree of ground saturation, degree of permeable soil, and amount of vegetation can be determined, then these can be correlated to give short-term prediction, in this case called a forecast, of possible floods. If a forecast is issued, then a flood warning can be communicated to warn the public about the possible extent of the flood, and to give people time to move out of the area. Such forecasts are very useful for flooding that has a long lag time between the storm and the peak discharge

3.9.2 Instrumentation Networks

Flood warning and forecasting systems usually rely on a network of meteorological, river and/or coastal instruments. Individual types of instrumentation may also be combined; for example, an automatic weather station may be installed on a wave buoy, or a rain gauge at a river gauging station. Monitoring networks can also serve a range of purposes in addition to flood warning and forecasting, such as water resources monitoring, marine forecasting, and climate change monitoring, requiring a compromise between these different applications. For example, a water resources gauge may be installed close to a river confluence to monitor the entire runoff from a catchment but, at high flows, suffer from backwater influences from the main river, possibly making it unsuitable for use in a flood forecasting application.

3.9.3 Integrated Flood Management

The Integrated Flood Management (IFM) approach aims to maximize the net benefits from flood plains and at the same time reduce loss of life due to flooding, flood vulnerability and risks, and preserve ecosystems and their associated biodiversity within the overall framework of IWRM. The concept recognizes the benefits of smaller more frequent floods, the significance of flood plains and the increasing development demands they face.

Floods offer significant benefits but at the same time recognizing the disruptive nature of floods requiring interventions that can integrate:

- Structural and non-structural measures;
- Land and water management;
- Ecosystem preservation and development needs; and
- Short- and long-term flood management measures.

Integrated Flood Management aims to maximize the efficient use of flood plains while minimizing the loss of life from flooding. It proposes these key elements:

- Adopting a best mix of strategies, both structural and non-structural;
- Managing the water cycle as a whole while considering all floods, including both extremes;
- Integrating land and water management, as both have impacts on flood magnitudes and flood risks;
- Adopting integrated hazard management approaches, taking into consideration the risks due to all related hazards such as landslides, mudflows, avalanches, storm surges and tsunamis and creating synergies; and
- Ensuring a participatory approach to develop a sense of ownership and reduce vulnerability.

3.10 Detection

It is the process of detecting flood hazard through the study of rainfall and flood magnitudes with the help of devices. It is an assessment of the availability, quality and reliability of existing real time data on rainfall, rivers, tides etc. (as appropriate), and installation of new sites if required

3.11 Alert systems; target groups

Flood forecasting and early warning is used for alerting the likely damage center well in advance of the actual arrival of flood, to enable the people to move and also to remove the movable properties to safer places or to raise platforms specially constructed for this purpose.