Flood Forecasting and Early Warning

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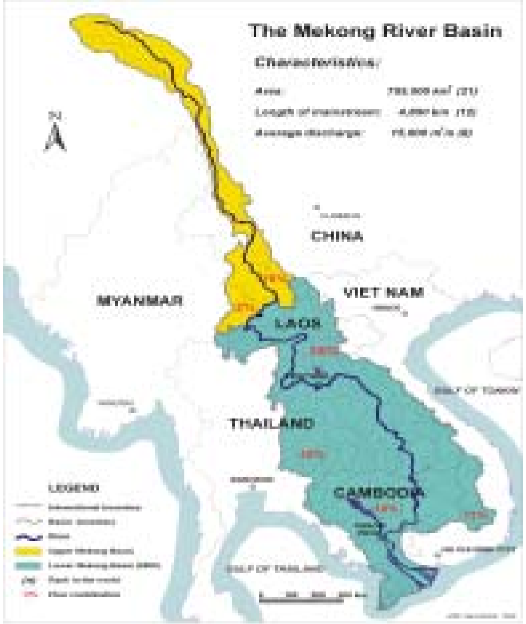
Introduction

Flooding in the countries in the Lower Mekong River basin represents the greatest natural disasters and its occurrence is becoming frequent and causing increased loss of life and destruction of property. It is a natural phenomenon beyond the human control and will occur inevitably from time to time so all that can be done is to find the ways to mitigating to damage they cause. Disaster prevention measures including structural and non-structural ones have been applied to lessen the impact of flooding on the social and economical conditions of human settlements in floodplains or low-lying coastal areas. Since the structural measures like dam construction require a big investment and they would be a good long-term solution, numerous attempts have been made to employ the non-structural flood loss prevention measures to assist in minimizing the losses and one of which is flood forecasting. Flood forecasts constitute a direct means or the reduction of flood damage and loss of human life. Advance warning of an approaching flood permits evacuation of people, livestock, and property with no loss except for the cost of removal. The relatively low ratio of cost to benefit for a flood forecast and warning service makes it an ideal flood protection measure in many areas where physical means can not be economically justified.

The Mekong River Basin - hydrology and flood

Physical features

The Mekong, Chinese Lancang, one of the great rivers of South East Asia (4,180 km long) and is ranked among the largest rivers of the world. Form its marshy source on the Rup-sa Pass in the highland of Tibet and flow generally southerly through Yunnan province in deep gorges and over rapids. Leaving Yunnan, the Mekong forms the Myanmar-Lao border, and then curves Eastward and Southward through North West Lao PDR before making part of the Laos-Thailand border. From South West Laos the river descends onto the Cambodian plain, where it receives water from Tonle Sap during the dry season by way of Tonle Sap River, during the rainy season, however, the floodwaters of the Mekong reverse the direction of the Tonle Sap River and flow into Tonle Sap, a lake that is natural reservoir. The Mekong River finally flows into the South China Sea through many tributaries in the Mekong Delta, which occupies Southeast Cambodia and Southern Viet Nam. The Mekong River Basin covers a drainage area of 795,000 km2 of which some 606,000 km2 is the Lower Mekong basin that starts near Chiang Saen (Thailand) at the junction of the borders of Thailand, Laos and Myanmar (fig. 1).



Flow Contributions:

Upper Mekong (18%)

- China – 16%
- Myanmar – 2%

Lower Mekong (82%)

- Cambodia – 18%
- Lao – 35%
- Thailand – 18%
- Viet Nam – 11%

Climate

The climate of the Lower Mekong basin is tropical and governed by the seasonal monsoon winds: northeast and southwest, each for about 6 months of the year. The southwest monsoon begins in May and continues until September/October; then following a brief period of instability, it is replaced by a reverse air stream, the northeast monsoon from November to mid March. The period in which the southwest monsoon blows called the wet season or the rainy season and is characterized by heavy and frequent rain, high humidity, maximum cloudiness and high temperature. A short dry period of one or two weeks is normally experienced between June and July due to the influence of high altitude anticyclone circulation. After the dry period rainfall becomes more frequent, and heavy rainfall is experienced in tropical storms and typhoons, which enter the Mekong basin from the east during wet season.

Winter (dry season) from mid-October till March the area is affected by the northeast monsoon, which originates in the cold air masses occurring in China and the polar region. During the period when this monsoon blows very little precipitation occurs, humidity is low, the sky is clear and temperature are relatively low.

Rainfall

Annually, from May the southwest monsoon increasingly affects the basin, especially in the months August, September, and October when the monsoon becomes strongest. During this period various weather disturbances develop in the eastern area such as intertropical convergence zone, depression or storm and they often cause heavy rain over the basin.

The mean annual rainfall ranges from 1,000 mm near the center of Northeast Thailand, to 4,000 mm in the Truong Son Mountain range lying between Lao and Viet Nam (tab. 1). Between 80 to 90% of the precipitation occurs in the wet season and rainfall of the three wettest months (Aug., Sep., Oct.) makes up 40-50% of the annual total and some of 18-20% of the annual rain total falls in the wettest month (normally September). The effect of the topography is clearly seen in the rainfall distribution over the basin and adjacent areas. Rainfall is highest on the windward side of mountainous ranges lying across the path of the southwest monsoon such as Truong Son range, which runs across Laos, eastern Cambodia and adjacent areas in Viet Nam. The areas in the right bank of the river and Korat plateau have less rainfall (more or less 1,000 mm)

The dry season commences in mid October or early November when the northeast monsoon displaces the southwest one. This period is characterized by high atmosphere pressure, low humidity and temperature. Rainfall amount of this period accounts for 10% of the annual total.

Table 1: **Annual Rainfall in the Mekong Basin**

Region	*Annual Rainfall (mm)*
Lancang River Basin	Variable. 600 mm in North, 2700 mm in South
Northern Highlands	Wet. 2000 to 2800 mm
Korat Plateau	Relatively Dry. 1000 to 1600 mm
Annamite Chain	Wet. 2000 to 3200 mm
Southern Uplands	Very Wet. Up to 4000 mm
The Mekong Plain	Variable. 1100 to 2400 mm

Source: MRC, Appropriate Improvement of Hydrological Network, 2001

Flow distribution

The climatic pattern of distinct wet and dry seasons is reflected in the stream flow records of the Kong and its tributaries which show marked season variations. Each year about 500, 000 million cubic meters of water empties into the ocean off the delta. The flow of the Mekong and its tributaries is closely related to the rainfall pattern. Generally the main river begins its rising course following the starts of the rains in May and at upstream locations reaches its peak in August, September; or October, meanwhile for downstream locations the peaks occur a little bit later (September, October or November). It then falls rapidly until December and afterward recedes slowly during the dry period of the year to reach its lowest level in March/April, just before the onset of the monsoon.

During the wet season the Mekong carries an enormous volume of excess water resulting in severe flooding and substantial damage almost every year in the fertile flood plain along the main stream and the major tributaries, as well as in the vast flood plain of the delta. In contrast during the dry season a serious reduction in flow often leads to drought in many areas, with a resultant shortage of water for domestic use and agricultural development.

Flow of the flood season accounts for 70-80 % of the annual flow. The flow of the three wettest months makes up 60% of the annual flow, in some locations this portion would get 80%. The maximum flow normally occurs in the months August, September, or October. Maximum monthly flow may account for 40-50% of the annual flow. The dry season lasts 6 or 7 months, but flow of this season makes up about 15-20% sometimes only 7-8% of the annual flow. In the Mekong the ratio between 10% low flow and 10% high flood discharge is approximately 50. However, the Tonle Sap system, which acts as a natural reservoir and regulates discharges to downstream areas, mitigates extremes between maximum and minimum flows. During the wet season, the discharge capacity of the Mekong and Bassac Rivers south of Phnom Penh is inadequate to handle flood flows. This results in backflow up the Tonle Sap River and into the Great Lake, where water levels can rise up to nine or ten meters.

The Great Lake and the Tonle Sap River have a significant effect on flood flows and flood level in Cambodian and Vietnamese Delta. Total natural storage capacity of the Great Lake and the Tonle Sap is estimated to some 150 billion m3. Depth and reservoir area are shown in Table 2.

Table 2: Depth and Reservoir Area of the Great Lake

Description	*Dry season*	*Wet season*
Depth of water	1-2 m	9-10.8m
Water Surface	250,000-300,000ha	1,000,000-1,400,000ha

At Kratie in Cambodia the average discharge equals 15,000 m3/sec and the average discharge of the three flooding months is 24,000 m3/s thus during flood season large parts of Cambodia and Vietnam are inundated.

Flood situation in the region

Flood in the whole of the Mekong River Basin is a common feature associated with cyclonic conditions emanating from the prevailing monsoon. In the Mekong Basin Records indicate that the main causes of floods are related to heavy incidence of rainfall exacerbated by other local factors. Although both major and minor flood have occurred during all seasons, the majority of documented events have taken place during the period between September and December, where the potential coincidence of primary causes is highest.

Direct impact of flooding is in many cases substantial. The damage attributable to flood are very considerable and average several million $ per year. A very accurate delineation of the flooding extent at any given time would prove invaluable for estimating flood damage and in adequately managing flood damage compensation.

The Mekong River along with numerous tributaries carries an enormous volume of water during the wet season resulting in widespread and often severe flooding causing substantial damage almost every year in the fertile plains along the mainstream and tributaries.

In the past few decades (1966-2001) the basin has experienced several big floods, one of the biggest flood in the history of the Mekong River occurred in 1966 which caused severe damage to infrastructure and crop in the basin and total damage caused by this flood was estimated at US$ 56.5 million. Apart from the 1966 flood there were some another big floods occur on the basin in the years of 1971, 1978, and 1995, 2000, and 2001 and the 1971 flood is regarded as a biggest flood occurred in the Mekong Delta, which caused extensive damage to the delta area, hundred millions of dollars worth of damage and hundreds of lives in Viet Nam were reported death.

The most fertile lands of the Mekong basin lie in the densely populated flood plain. The Vientiane-Nong Khai area is the largest settlement one. Along the mainstream from Chiang Saen down to Pakse, most of the urban areas suffer from occasional flooding, usually few times a year.

Flood magnitude, affected areas, as well as duration of flooding depend on local condition and distribution of rainfall over the basin. In the upper reach from Chiang Saen (Thailand) to Thakhek (Laos)/Nakhon Phanom (Thailand), the maximum flow was recorded in the 1966 flood. In the middle reach from Savannakhet (Laos)/Mukdahan (Thailand) to Pakse (Laos), the maximum discharge was observed in the flood of 1978. Meanwhile the highest flood in Cambodia at Kratie was in 1939 and the maximum water level at Chau Doc in the Mekong Delta was recorded in 1961 flood. The upper reaches, there are areas which are subject to direct flooding from the Mekong River on both banks.

In the Mekong Delta (in Cambodia and Viet Nam), where the areas are relatively low and flat, the frequency and area of flooding is greater than in Laos and Thailand. The floods are caused not only by direct flooding from the Mekong, but also by the backwater effect from the Tonle Sap River..

Flood preparedness measures

It is necessary to recognize the probabilistic nature of floods - a bigger flood that overwhelms other management measures in place can always occur. The likelihood of occurrence of such a flood may be small, but the flood will certainly occur - it is not a matter of 'if' but of 'when' and whether flood-prone communities can successfully manage the onset, occurrence and aftermath of such a flood. Preparedness Measures are therefore required to assist the flood-prone community dealing with such a situation.

Three basic measures of Flood Preparedness are to be distinguished: Flood Forecasting, Flood warning and Flood Awareness. The success or otherwise of flood emergency management will be judged solely by the real-life flood experience of flood-prone individuals and communities. It is pointless having the best flood forecasting system that money can buy if flood warnings cannot be effectively delivered to flood-prone communities. Similarly, the benefits of flood warning are largely lost if flood-prone individuals do not know how to effectively respond to flood warnings (flood awareness).

Flood forecasting

Flood forecasting or flood prediction aims to estimate the size, timing, and extent of a flood before it actually occurs. Flood forecasts of downstream discharges and flood levels are typically based on rainfalls and water levels measured in upstream catchment areas, soil moisture and other conditions in the catchments and on forecast rainfalls over the catchment. The reliability and lead-time of forecasts depends largely on the size of the catchment, the larger the catchment the better and longer forecasts can be. Thus, for the mainstream of the Mekong, it is possible to provide good forecasts up to 5 days ahead. All flood forecasts contain uncertainties and errors. It can be misleading to accept forecasts as 'totally accurate', especially if forecast water levels are close to some critical level. The question should always be asked - 'What are consequences if the forecast is wrong?' In other words, how sensitive is the resulting hazard to the accuracy of the forecast. A situation where there is a marked change in hazard depending on the accuracy of the forecast will require a different response to a situation where hazard is insensitive to the accuracy of the forecast.

Flood warning

Flood warning aims to alert flood-prone communities of an impending flood. In the four MRC member countries, a hierarchical series of agencies are typically involved in the warning process. Forecasts and the associated warnings are typically generated by a central (State) agency, that then delivers the warnings to a provincial agency, that in turn delivers the warnings to a district agency, that in turn delivers the warnings to villages. There is the potential for considerable delay in this warning process. The delivery of warnings can be made much quicker by using radio and television. Typically, such warnings can be only general in nature. The most effective warning systems use both channels - mass media and agencies.

Flood awareness

Even if a warning is reliable and timely, its benefits will be diminished if the population at risk does not know how to respond effectively to reduce personal hazard and damage to their goods and possessions, i.e. if the flood awareness level of the flood-prone population is low. Training programmes at the village level are required to increase and sustain flood awareness so that villagers obtain the best value from flood forecasts and warnings.

2.4 Flood Preparedness Issues

- How effective is the current flood forecasting system - is it adequately accurate, reliable and timely? How can it be improved? Are additional forecast points needed?

- Do agencies or communities conduct a post-flood assessment and map the communities that flood as a result of a flood of a particular intensity?
- How effective is the current flood warning system – are warnings accurate, timely, believable and believed? Are the mass media being used effectively to disseminate warnings? Is there good integration between flood forecasting and flood warning activities? Is there good and effective integration between the warning activities of the various agencies (State, Provincial, District, Commune and Village) involved in the flood warning process?
- How prepared are flood-prone communities to deal with a flood emergency, i.e. what is the level of flood awareness? Are training programmes in flood awareness and preparedness available for delivery to villagers? How often are such programmes delivered?

Conversion of forecasts into warnings

Despite the dramatic developments in many areas of science and technology, destructive floods have not been eradicated. They occur frequently, causing death toll and severe material losses. In order to build an efficient flood preparedness system, a truly holistic perspective is needed, embracing a suite of components, such as monitoring, forecasting, warning, its dissemination, and response. A weakest link in the above chain decides on the performance of the whole system. In an ideal system, an accurate forecast is translated into reliable warning, which in turn is broadly and effectively disseminated to the communities at risk who take adequate loss-reducing actions.

Although such notions as forecast and warning are intuitively self-explanatory, different interpretations can be found in the professional literature, where these terms are defined as: Flood forecast- evaluation of an event in real time leading to the issue of a general alert about hazardous conditions; Flood warning- contains additional information, including recommendations or orders for action, such as evacuation or emergency flood proofing, specifically designed to safeguard life and property.

A flood forecast should give information as to when (timing), where (location), and how intense (magnitude) natural disasters are likely to occur in the near future (minutes, hours, days, up to weeks), how they will travel downstream and evolve, and what secondary effects they may cause. A warning is a communicated message that hazard is producing specific risks for a particular segment of the population. Warning convert scientific terminology of forecasts into popular form, usually with expressive terminology, so that the effected communities are not only informed, but also sufficiently impressed that they take remedial action before and during the flood disaster. The warnings should capture the nature of the loss-reducing action, being tailored in terms of their contents and delivery, to achieve an optimal response from an intended group of recipients.

Flood warning is a complex, socio-technical process. The production and dissemination of an early flood warning can be seen as a dynamic, socio-technical process involving different disciplines, stakeholders, decision-making levels, and degrees of uncertainty.

Warning production and dissemination can be described as a series of interrelated technical and organizational actions, purpose of which is to "translate" an observation (e.g. surpassed water level, or "flood threshold") into a stimulus triggering a specific response, possibly pre-formatted (individual or collective disaster response). Since a so-called "zero risk" situation cannot be obtained, nor reached, one major function of flood warning therefore is to care for existing "residual risk". This is the risk that theoretically remains after all other mitigation measures (land-use, water management, flood control) have been taken. In that sense, flood warning is expected to enable society to provide a timely disaster response: "plan for failure"; "expect to be surprised". In that sense, the time of early warning can therefore be seen as the "last step" of the so-called "hazard mitigation and disaster management cycle, before the disaster strikes.

The "classical" approach considers the "warning chain" as a succession of interconnected elements. This chain can be seen as a complex socio-technical system, that mixes scientific, technical, organizational and social factors with this in view to producing the warning decision. Any flood warning system is subject to failure: limited availability of data, technical limits of modelling. coexisting different professional "cultures" and "languages", lack of organizational procedures for information exchange, fragility of communication network, misunderstanding of warning by receivers, lack of interaction with grassroots level for real-time information exchange.

Flood warning can be seen as a social construct as well since the warning message usually serves as starting point for individuals and groups to make decision, people usually process the warning message according to a series of phases, that can be described as follows: 1) hear the warning: 2) understand the message; 3) believe the message content; 4) personalize the information; 5) decide and respond (action taking before the flood occurs: protection, evacuation, search for additional information)

A sentiment has been frequently expressed about considerable advances in forecasts but progress in warning lagging behind. Formulating warning messages one needs to consider that:

1. Scientific specificity may not be needed, but the basis of warning must be credible;
2. The warning message must explain the degree to which a specific area is at risk;
3. People must be told what to do to reduce their exposure to danger. Among the criteria or indicators of warnings are such as: warning errors ratio, penetration of warning, degree of satisfaction, etc.

To some extent, warning related to a disaster that has not materialized, versus errors of the second kind-lack of warning against a disaster that actually occurred. A disaster has not occurred, the warning, and the evacuation, were justified, and taken positive by the population- the risk of dike failure was very high.

A warning should be phased in a form and language, which can be understood by the intended audience. Warning systems should reflect the needs of the public.

Forecasting and warning systems are often seen as relatively inexpensive non-structural measures of flood protection. They are advantageous alternatives to politically unpalatable permanent evacuation of floodplains and to very expensive, and also politically controversial, large structural flood protection measures (or costly upgrades of existing infrastructure).

Flood forecast and early warning at MRCs

Flood forecasting is one of the solutions to overcome the adverse effects of floods. Flood forecasting and warning systems are cost-effective means of reducing the damaging impacts of flood. By enabling early identification of flooding and timely protection or evacuation of potentially flood inundated area, it is possible to minimize, if not completely obviate, damage caused by flooding

Flood forecasting aims to estimate the size, timing, and extent of a flood before it actually occurs. Flood forecasts of downstream flow/level are typically base on rainfall and water levels measured in upstream catchment areas, soil moisture and other conditions in the catchments and on forecasts of rainfall over the catchment

A progamme for basin-wide flood forecasting was established in accordance with the United Nation ECAFE report on "Proposed Implementation of a Basin-wide Flood Forecasting system for the Lower Mekong Basin" dated December 1969.

The Mekong Secretariat initiated flood forecasting operation in the Lower Mekong Basin in 1970. The objective of the forecasting is to provide the information on the future state of a river in order to minimize the negative effects of floods and provide warning to those people who live in the vulnerable areas. Since then this operation is repeated annually during flood season. Flood forecasts at Hydrology Unit, MRCS are prepared on working days during the months July to October. The Mekong River Commission Secretariat applied SSARR model for forecasting for the upper and middle reaches of the Lower Mekong -from Chiang Saen (Thailand) to Pakse (Laos) and regression method for lower reaches from Stung Treng to Tan Chau and Chau Doc in the Vietnamese Delta.

Flood Forecasting System - 5-day forecasts are being displayed on the web (www.mrcmekong.org) on a daily basis. The forecasting system will be enhanced when the telemetering network of water level and rainfall stations comes online, including two stations in China. A project proposal for the Flood Forecasting and Warning dissemination System has been prepared by the MRCS.

Improvement of flood forecast and early warning system

After the flood 2000, there have been considerable investments in MRC, aimed at improvement of flood preparedness systems, including strengthening the flood forecasting and warning systems (e.g. broader use of modern technology, radar, GIS). Efforts have been made to upgrade the monitoring systems, to render stream gauges more robust (AHNIP), and communication and data transmission systems, more reliable than before.

It is clear that the distribution of responsibilities, understanding of responsibilities and complicate links between the actors need to be improved. Typically, shortcuts would help and delegating mandate and responsibility to lower level. According to the legislation existing during the flood, the lower level authorities were not entitled to announce the alert or alarm status. They had to wait for the statement of this status being issued by the Provincial Anti-flood communities and such decisions came delayed by many hours. Also the circulation of information was deficient- hydro-meteorological stations reporting to their regional branches (albeit making information available, on request, also to local authorities).

A task force of FMM and Flood forecasting core team has been set up at the Secretariat to devise a high tech, state of the art floodwater warning system, and develop means of flood forecasting. Among the necessary activities were:

- Improvement and coordination of flood warning services and improvement of long-term flood forecasts
- modern flood forecasting and warning system-to extend the warning time and reduce damage, for the whole Lower Mekong Basin.

This includes recognition of needs of modernization of the network of stage and rain gauges, automatization, data transmission, technical upgrading of flood warning centers, including telecommunication facilities (phone, radio, fax, working also without mains supply), creation or modernization of system of informing and warning the population (via media, or automatic warning), enhancing regional, inter-regional flow of information related to flood, precipitation, observations, forecasts and developing forecast models (based on quantitative precipitation forecasts, rainfall-runoff and flood routing).