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REGIONAL CONSULTATION WORKSHOP ON EARLY WARNING SYSTEMS ON DISASTER MITIGATION

Overview of the Natural Disaster and Flood Forecasting and Warning Systems in the Region^f

by
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I. OVERVIEW OF NATURAL DISASTERS IN THE REGION

Natural disasters have profound impact on the quality of life through their destruction of food crops and livestock, shelter and other aspects of the built environment, and forced dislocation of households and communities. But their toll on lives and the instant poverty that constitutes their most devastating impacts (UNESCAP 1995)¹. The effect of natural hazards on the loss of human lives is directly related to the poverty levels in a given country. National and regional efforts for natural disaster reduction should therefore be closely linked with poverty alleviation and economic and social development activities.

In the Asian and Pacific region, losses caused by natural disaster events are particularly damaging, depriving countries of resources which could otherwise be used for economic and social development. The toll from such disasters is most severe and tragic in the least developed and developing countries of the region, which have sometimes had their development goals set back years and even decades as a consequence of major disaster impacts. Since the International Decade for Natural Disaster Reduction began in 1990, the total number of deaths caused by natural disasters in Asia and the Pacific has exceeded 200,000. The estimated total damage to property was already about US\$ 50 billion until the Kobe earthquake in 1995 and very heavy flooding in China in 1995 and 1998. In the 1991 cyclone and storm surge event in Bangladesh, 140,000 people perished, whilst the flood of 1998 affected the lives of 25 million people. The total damage by the 1995 flood in Bangladesh was estimated at US\$ 530 million, resulting in a negative effect of 5 per cent on the growth of the gross domestic product (GDP) of that country². In that year, various provinces of China were affected by extensive floods during the month of July, affecting 220 million persons, taking 2,300 lives and causing a total loss of US\$ 12.5 billion, equivalent to 4.5 per cent of the GDP of that country.

Over the past few years the region has suffered exceptionally heavy losses from natural disasters. With respect to floods alone, in 1997 the total damage was estimated at about US\$7 billion in seven countries, according to an annual ESCAP survey on water-related disasters³. In 1998, the most extreme floods in several decades have devastated some countries in the region, particularly Bangladesh, China, India, Republic of Korea and Viet Nam, resulting in a total damage estimated over US\$23 billion. The flood in 1998 in China was the most severe one in the past 44 years. According to governmental estimates, 223 million people - one fifth of China's population were affected, 3,004 people died and 15 million were made homeless. About 15 million farmers lost their crops. The floods caused severe damage to critical facilities such as health clinics, schools, water supply, and other infrastructure such as roads, bridges and irrigation systems as well as industrial facilities. In October 1999, the State of Orissa in India was most severely affected by a super cyclonic storm in the Bay of Bengal, causing the death of nearly 10,000 people, affecting nearly 13 million people in 14,643 villages, causing damage to 1.8 million hectares of crop, 1.65 million houses and loss of 444, 000 livestock and 9,085 boats. Meanwhile, El Niño Southern Oscillation (ENSO)-

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¹ A Mid-Decade Report on Natural Disasters in Asia, presented at the Yokohama World Conference, UNESCAP, 1995

² Modalities for environmental assessment: Flood loss reduction in Bangladesh, ST/ESCAP/2003, Nov 1999

³ Water Resources Journal, ESCAP, Issue No. 197, June 1998

related droughts caused water shortages and forest fires in Indonesia and the Philippines and affected neighbouring countries as well. In July 1998, the 10-metre tsunami that hit Papua New Guinea took more than 2,000 lives in several coastal villages. In January 1995, the Kobe earthquake killed over 5,000 people in addition to tremendous damage it caused. In August 1999, Turkey was affected by a severe earthquake which caused tens of thousands of dead and injured, destroyed nearly 100,000 housing units making some 100,000 families homeless. The total wealth loss was estimated by the World Bank to be in the range of US\$ 3 – 6.5 billion (equivalent to 1.5 to 3.3 per cent of the gross national product)⁴.

Land degradation and desertification are other major disasters, which pose serious threat in Asia in the wake of growing population and enhanced food demand. The countries most affected by desertification are China, Islamic Republic of Iran, Afghanistan, Mongolia, Pakistan, India and the Central Asian States. Although desertification process can be seen as a complex interaction of natural and socio-economic forces, in fact human-induced factors such as deforestation, faulty land use practices, mismanagement of irrigation systems and overgrazing, are responsible for accelerating the process. In terms of desertification, the region is among the world's worst affected areas with 35 per cent of the region's productive land considered to be desertified, including 70 million ha in rainfed areas and 16 million ha in irrigated croplands.

Forest and bush fires have always been a hazard in the region but recently they reached catastrophic dimensions. During 1997-1998, massive fires in Southeast Asia destroyed millions of hectares of forest, caused more than \$4.5 billion in damage. The fires were caused by the combination of drought, slash and burn agriculture, and exploitation of forests that created a thick, choking haze which covered the subregion, creating serious health problems; causing accidents on land, at sea, and in the air; disrupting transportation systems and resulting in a steep drop in tourism in parts of the region where declining economies could hardly afford it.

Impacts of natural disasters in the region may reach catastrophic levels. For example, in Bangladesh the damage due to recent floods reached above 5 per cent of GDP and in DPR Korea, economic constraints, further precipitated by a series of natural disasters since 1995, affected 60.4 per cent of children with moderate to severe malnutrition amongst the surveyed group and approximately 200 per 100,000 population are estimated to be suffering from tuberculosis. According to some estimates, the Kobe earthquake in Japan requires rehabilitation costs of over US\$ 100 billion.

1. Causes of natural disasters

The recent regional surveys conducted by UNESCAP showed that the Asian and Pacific region is one of the most vulnerable regions of the world to disasters, and experiences a wide variety of natural hazards including floods, cyclones, earthquakes, droughts, tornadoes, debris flows, hailstorms, storm surges, tsunamis and haze. Table 1 presents the relative intensity of most important natural hazards faced by some vulnerable countries in Asia.

Tropical cyclones occur more frequently in the Asian and Pacific region than in any other part of the world, and are usually accompanied by severe flooding. While riverine flooding in the region continues to be a common occurrence causing substantial annual damage, the impact of flash floods is also becoming increasingly important. Urban flooding has become a major potential hazard in terms of its economic and social impact, as a result of the rapid urbanization process and uncoordinated infrastructure development. With respect to coastal flooding, storm surges have the potential to cause substantial loss of life and property damage in large and heavily populated deltaic areas, such as those of Bangladesh and Viet Nam, and tsunamis generated by submarine earthquakes can also become very destructive as experienced in Papua New Guinea in July 1998.

Cyclone-related disasters identified by the responses included floods, strong winds, landslides including mudflows, storm surges and tornadoes. Floods were the most common disaster experienced practically in almost all countries in the region and rated to be the most severe by many responses. On an

⁴ United Nations Office for the Coordination of Humanitarian Affairs, October 1999

averaged term of severity, the cyclone-related hazards can be classified in the following order: (1) flood, (2) strong winds, (3) landslides, and (4) storm surges. More details of water-related natural disasters in Asia are given in Annex I.

Table 1. Relative Intensity of Natural Hazards faced by Selected Countries in Asia

COUNTRY	Cyclone	Flood	Drought	Landslide	Tsunami	Earth-quakes	Volcanoes	Fire
Australia	S	S				L		S
Bangladesh	S	S	S	L	L	L		L
China	M	S	S	L	L	S		M
Cook Islands	M	L	S	L	M	L		
Federated States of Micronesia	M	S*	S	L	S	L		
Fiji	S	S	M	S	S	M		
Hong Kong, China	M	L		M				M
India	M	S	S	L		M		M
Indonesia	L	M	M	L	L	S	M	M
Kiribati	L	S*	S	L	S	L		
Islamic Republic of Iran	M	S				S		
Lao PDR	M		L					
Malaysia	M	M	S	L	M			L
Marshall Islands	M	S*	S	L	M	L		
Myanmar	M	M	M	M		S		S
Nepal	M	L*	M	L		M		M
Niue	M	L*	M	L		L		M
Pakistan	M	M*	M	L	M	S		L
Philippines	S	S	L	S	S	S	M	M
Papua New Guinea	L	S	M	S	S	S	S	L
Palau	M	M*	M	L	M	L		
Solomon Island	S	S	L	S	S	S	S	L
Samoa	M	S	L	S	S	M	L	L
Sri Lanka	M	S	S	L				L
Thailand	M	S*	S	L		L		L
Tokelau	M	S*	S	L	S	L		
Tonga	S	M	M	L	S	S	S	
Tuvalu	L	S*	M	L	S	L		
Vanuatu	S	S	L	S	S	S	S	L
Viet Nam	M	S	L	S	S	L		L

* coastal flooding Source: Asian Disaster Preparedness Center; DHA; UNESCAP. Legend: S = severe; M = moderate; L = low

Because of the continuing rapid population growth in the countries of Asia and the Pacific, people, mostly the poor, are being forced to settle at squatter areas in large cities, usually inhabiting low-lying flood-prone areas, unstable hillsides or other disaster-prone marginal areas owing to the high cost of suitable alternative locations and the extremely high cost of new infrastructure and services. For example, in Bangladesh over a million people are living on islands formed by silt deposits and along the vulnerable flood plains and coastal areas. Over 85 per cent of the population of China live on alluvial plains or along river basins concentrated in one third of the total area of the country. The situation is quite similar in Viet Nam, where the dykes along rivers providing protection are sometimes breached by flood waters causing extensive inundation. In consequence, the number of persons vulnerable to natural hazards is increasing rapidly.

Geology-related disasters are generally one of the most destructive in terms of human lives lost. In a global survey covering the period 1970-1997 prepared by the Swiss Reinsurance Company, published in 1998, of the 40 worst catastrophes in terms of fatalities listed (with over a million deaths), 48 per cent were caused by earthquakes. The fact that 30 of the 40 catastrophes had occurred in the Asian and Pacific region (and 87 per cent of the casualties) highlights the importance of this issue for the countries of the Asian and Pacific region. However, most of the efforts of central and local governments have been aimed either at disaster mitigation or at post-disaster relief operations, and thus were more reactive rather than proactive in nature. Moreover, the continued population growth in the already heavily populated parts of the region will increase the number and size of large cities, placing more and more people and assets at risk in potential natural disasters.

Another factor that exacerbates the effects of natural hazards is the environmental degradation taking place in many countries of the region. The damage caused by natural hazards is higher in countries where environmental degradation is rampant. Deforestation, erosion, overgrazing, overcultivation and incorrect agricultural practices and the degradation of natural buffers amplify the effects of natural hazards. Land degradation and desertification pose a serious threat in the region in the wake of growing populations and enhanced food demand. A comparison of desertification among the continents indicates that the Asian and Pacific region is most severely affected in terms of loss of land productivity and agricultural output, whereas Africa has the highest percentage of desertified dry land.

2. Brief description of the natural disaster patterns

The impacts of the cyclone-related disasters were felt most severely at the local level, followed by the regional level and also at the national level. Impacts of floods are particularly important at the regional and national levels. In the survey conducted by UNESCAP in 2000 for the Typhoon Committee Area, it was reported that several members of the Typhoon Committee had tried to quantify the annual economic losses caused by cyclone-related disasters in monetary terms, which varied from US\$5.5 million in Hong Kong to as high as US\$1,960 million in Japan per year. Damages on special events were also provided such as the floods of 2000 which caused losses varying from US\$ 266 million in Viet Nam to US\$6.14 billion in DPR Korea. Attempts were also made in several countries to rank the severity of these cyclone-related hazards according to the magnitude of impacts, such as provided in Malaysia and the Philippines:

Economic loss (US\$)	Flood	Strong winds	Land slides	Storm surges
Malaysia⁵	50 million	2 million	3 million	1 million
Philippines	1,829 million	1,691 billion	1,290 million	no data

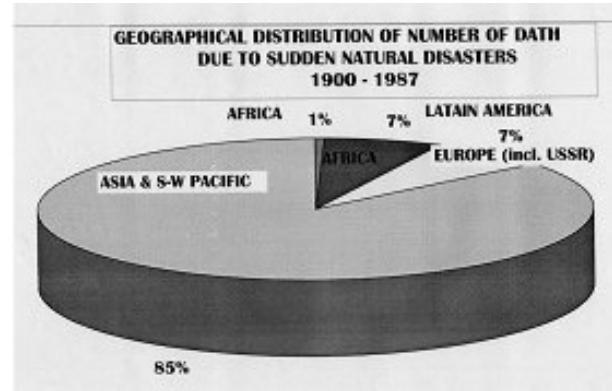
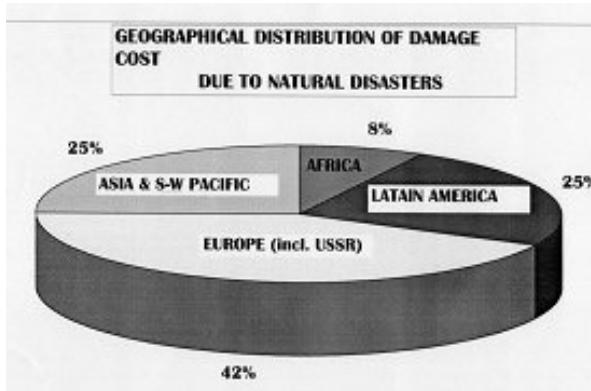
In general, impacts of river floods were listed to be high in many countries and the impacts of urban floods were estimated to be high in several countries, such as Japan and Malaysia. Flash floods were found to be frequent in many countries while data on coastal floods, particularly storm surges, were not readily available in most responses.

The UNESCAP region extends over a total area of about 35 million km², or 26 per cent of the world's land area. With nearly 60 per cent of the world's population and over 60 per cent of the total irrigated land, the region is more densely populated and more intensely cultivated than elsewhere. All in all, therefore, the potential for the occurrence of devastating natural disasters is much greater in the countries of Asia and requires particular attention if the severe toll of these events on life and property is to be significantly reduced. It is the purpose of this background paper to examine the extent of these disasters in further detail, to report upon the progress as well as constraints encountered in coping with the natural hazards, to assess achievements in integrating disaster preparedness into the national economic development process, and to identify priority areas for follow up actions.

⁵ Indication of the order of magnitude only

a. Geographical distribution

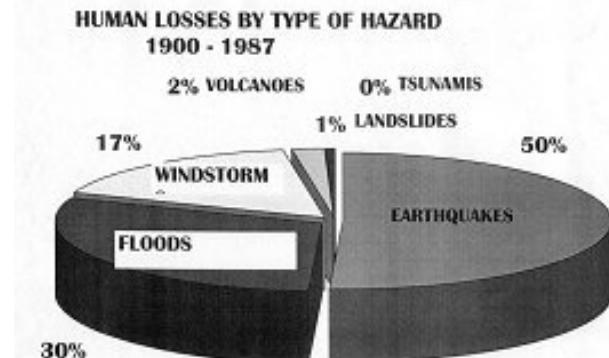
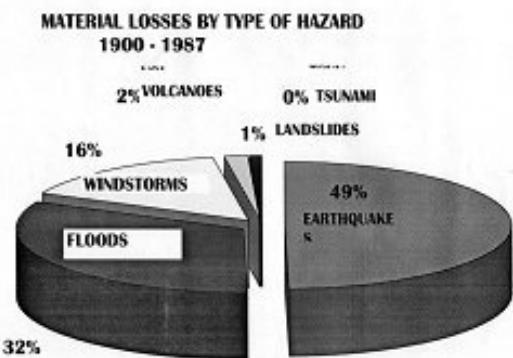
If you look at the occurrence of disasters and its effects, it does not always correspond to land area and population. As a percentage of the total cost of disasters worldwide, Europe accounts for over 40% and Asia 25%.



On the other hand, Asia-Pacific region accounts for 85% of human losses and is one of the big issues of the Asia-Pacific region even as it is succeeding economically.

b. Disaster types

By type, the material and human losses due to disasters are greatest for earthquakes. The rest is

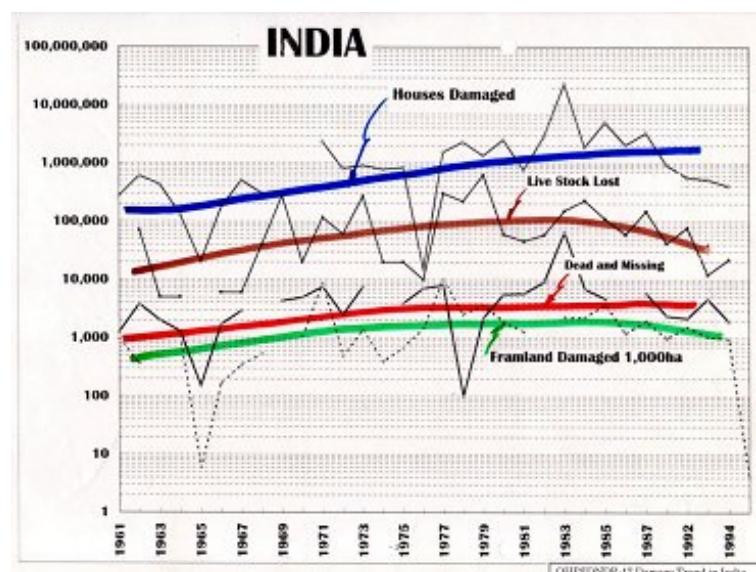


accounted for by floods and wind damage which is greater than expected. There are disasters like tornadoes which cannot be dealt with by advanced countries either, but for the most part wind damage can be attributed to a weakness in the houses' structure.

3. Damage trends in some of the Asian countries

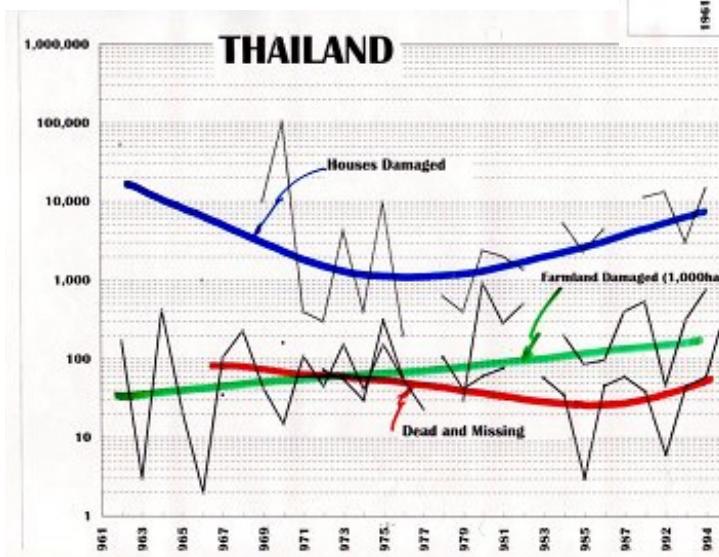
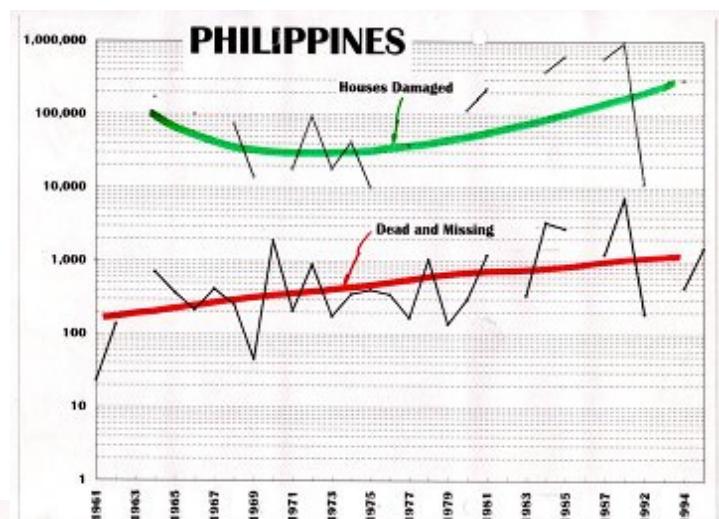
a. India

India is one of the Asian countries which have well developed statistical survey and compilation system. Indices show that damage caused by wind and water has been on the decreasing trend since 1982. However, overall, trends point towards an increase. Whether the decrease in recent years is a trend or statistical fluctuation is not known.



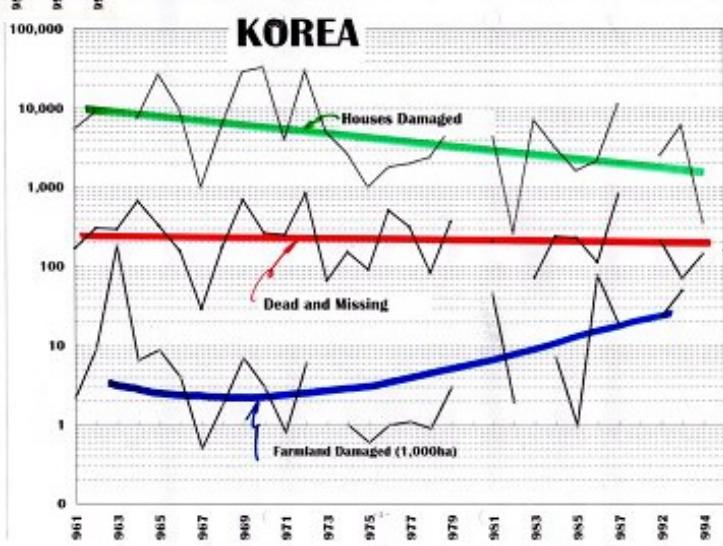
b. Philippines

In the Philippines, damage to houses, deaths and missing persons are on the increase. Damage to houses is relatively high because the Philippines lies on the path of cyclones and buildings are not strong enough to withstand them as well.



c. Thailand

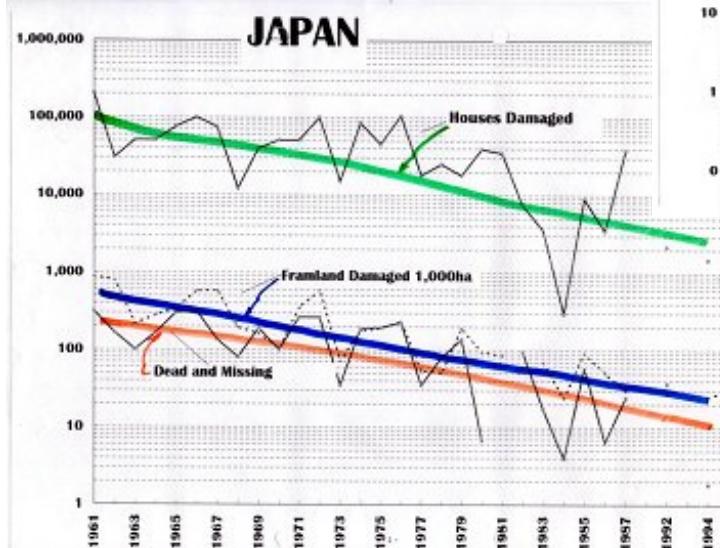
Thailand has relatively few disasters, but recently the urban type flooding of the Bangkok metropolis is becoming a big problem. This type of flood results in few human losses and buildings are not apparently damaged, however, its effect on the economy is immeasurable.



4. Experience in Korea and Japan

a. Korea

Korea is next to Japan in achieving rapid economic development. The fact that damage to agricultural land shows no statistical trend



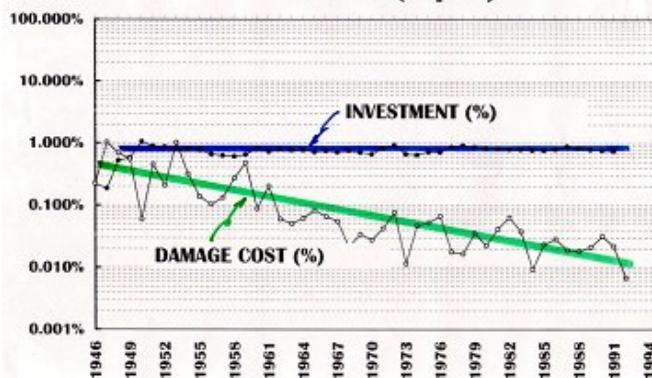
terms of ratio to national income has decreased surely.

may be a statistical matter. A decrease in housing and human losses may be attributed to efforts at disaster prevention.

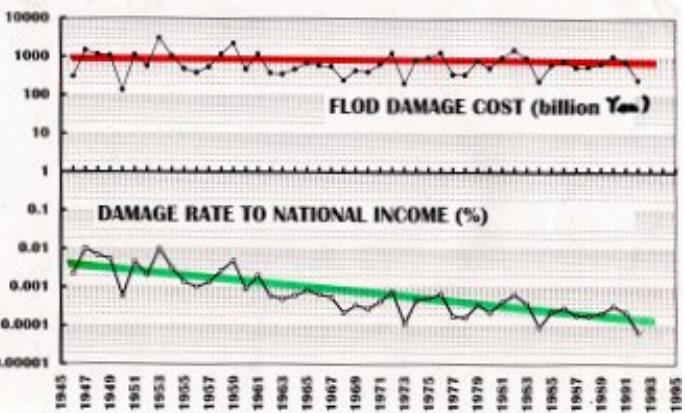
b. Japan

Japan stands in contrast to these countries. The index of damage has decreased one order since 1961. The cost of damage has not decreased in Japan, but the impact to the national economy in

INVESTMENT and DAMAGE to National Income (Japan)



DAMAGE COST AND ITS IMPACT (JAPAN)

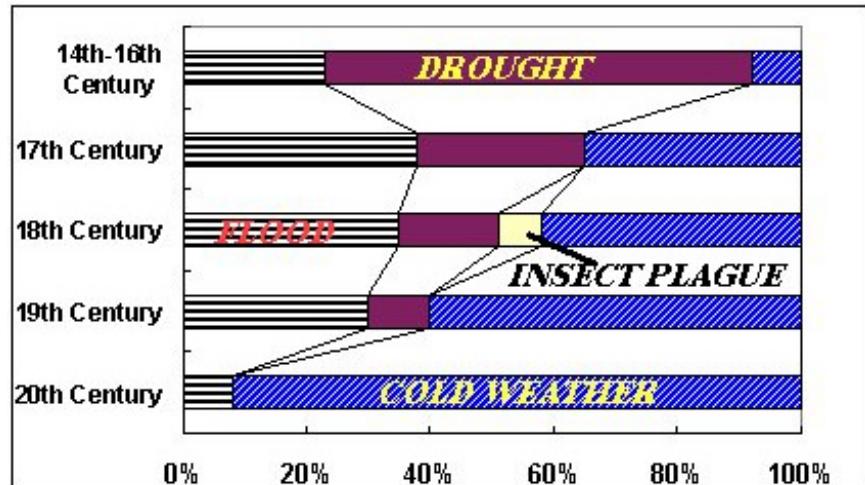


Behind these figures, there was a fact that Japan has spent around 1% of income on its disaster countermeasure since 1950's. Even with disasters caused by natural phenomenon, continued effort can greatly reduce damages.

5. Drought - another type of disaster -

Considering an increasing global population, drought is a major issue that needs to be dealt with. Currently, in Japan, it is said "there is no poor harvest in a dry year" and in fact in 1994, with one of the greatest water shortages in recent years, there was a good harvest. However, from the 14th to 16th centuries when irrigation facilities were inadequate, drought was the greatest cause of poor harvest. Later, as irrigation facilities became adequate, floods became the greatest cause of poor harvests, but as flood control measures were undertaken flood damages decreased as well.

Currently, the single greatest cause of poor harvest is unusually cold weather and event that opened doors for the import of rice was unusually cold weather in 1993. Either way, even with droughts which are considered difficult to deal with, a continued effort to provide adequate irrigation facilities will enable this problem to be overcome.



6. Remarks

Although it has been clear that the socio-economic impact of natural disasters has significantly increased during the past few decades, the trend of change in hazard frequency and intensity prevention is not obvious. It is important for the consultation workshop participants to share experience and perception on current trends in disaster patterns taking into account possible impacts of global climate change.

II. ADVANCES AND CONSTRAINTS IN DISASTER PREPAREDNESS AND WARNING SYSTEMS

1. Mitigation strategies

A variety of prevention and preparedness measures has been applied in the countries of the Asian and Pacific region, albeit with varying degrees of success and often in an uncoordinated fashion. To date, the principal thrust of the disaster mitigation strategies employed in the Asian and Pacific region has concentrated on disaster preparedness, rather than on disaster prevention. Whilst this approach has in many countries been successful in reducing the overall death toll associated with these hazards, the amount of physical damage has continued to mount. The prevention measures which can be directed towards the reduction of the effects of the hazard prior to its occurrence and the preparedness measures which may be implemented during and after the disaster will be summarized in the following sections. In summary, these mitigation measures attempt to lessen the impact of the hazard by adopting both structural and non-structural approaches. The objective of the structural approach is to control the effects of the hazard by using specific engineering works as the best means of protecting life and property. On the other hand, the objective of the non-structural approach is to modify susceptibility to the hazard through a range of controls and other non-engineering devices.

a. Water-related disaster mitigation

The most successful preventive measures employed to curb the destructive and injurious effects of natural hazards, such as tropical cyclones are building design and construction standards, established to assist buildings and other structures to resist wind and water damage. The range of measures available for protection against the effects of flooding is much wider than that available to reduce the impact of tropical cyclones. For water-related disasters, it may include civil engineering-oriented structural measures, such as channel modifications, flood storages and levees, as well as non-structural measures such as planning controls and flood proofing of buildings. These measures are designed and implemented in order to reduce the incidence or extent of flooding and storm surges and/or to minimize their effects.

The selection of the best mix of measures for application at a given location to prevent the occurrence of future disasters should be based on a consideration of all the available structural and non-structural options. The optimal mix of measures should be based on risk analysis and the economic performance of the overall scheme. Consideration of social and environmental factors in addition to the legislative and legal constraints should form part of the planning process.

Disaster preparedness covers those actions that are taken when a potentially hazardous event threatens to become a disaster. Preparedness activities are designed to reduce social disruption and losses to existing property and are an essential component of overall disaster planning. Although these activities can serve, in the absence of more permanent mitigation measures, to reduce the threat to loss of life and property, they are more effective when employed as a component of a comprehensive, overall disaster management plan.

Disaster preparedness is designed to minimize loss of life and property damage and to organize and facilitate timely and effective rescue and relief in the case of a disaster. It must be supported by legislation which can ensure readiness to cope with disaster situations when they cannot be avoided. It also includes forecasting and warning, the education and training of the population, and organization for and the management of disaster situations, including the preparation of operational plans, training of relief groups, stockpiling of supplies and provision of necessary funds. Furthermore, it should include disaster fighting and evacuation, relief and rehabilitation. To be effective, such disaster preparedness measures, including those which are taken when the occurrence of a hazard, such as tropical cyclone, flood or storm surge imposes the threat of a disaster, must be planned in advance.

The most important of these measures for helping to mitigate the effects of natural disasters is the development and implementation of effective forecasting and warning systems. These can be particularly

effective in reducing the potential damage by increasing the time between the prediction and onset of an event. To be effective they must include not only the latest techniques for the formulation of accurate forecasts, but also related communications systems designed to disseminate timely and accurate advice to the general public.

b. Geology-related disaster mitigation

Earthquakes are rather difficult to predict and when such prediction can be made there is usually little time to issue adequate warnings to the people. However, timely predictions of volcanic eruptions in the countries of the region, have enabled the concerned authorities to evacuate the people from danger zones before any harm was sustained. The Pinatubo volcano, which erupted in 1991 claiming over 800 lives, could have caused tens of thousands of fatalities. This saving of lives was mainly due to monitoring of the volcano, together with a warning and communication system which enabled 80,000 persons directly threatened in nearby areas to be evacuated. Similarly, the effects of tsunamis have been successfully dealt with in Japan by improved tracking and warning of the tsunamis and construction of appropriate structures. Nevertheless, there is still the need for each country to improve the quality of forecasts and warnings of natural hazards, and increase the lead time of warnings to enable areas likely to be affected to make advance preparations. There is also a need to give special emphasis to the improvement of communication links for the transmission of basic data and warning information on such natural hazards.

Hazard mapping and risk assessment have yet to be undertaken in much of the region. There is a need for comprehensive vulnerability analysis for disaster-prone areas, incorporating past disaster events, the socio-economic conditions of the population living in the area, and inventories of major structures of public concern. Risk assessment and hazard mapping would delineate areas vulnerable to geology-related natural hazards and the frequency, intensity, impact, etc. of each hazard.

As a preventive measure, earthquake-resistant designs for dwellings have helped reduce the number of casualties and prevent serious damage to buildings. Progress has been achieved in developing such mitigation measures to improve the safety of non-engineered structures such as ordinary dwellings and simple public buildings constructed with local materials in the traditional manner. In many countries reduction of loss of life and damage to property due to earthquakes has been made possible by the adoption of appropriate building design and construction. Nevertheless, a high number of lives is still lost in some countries, as was the case in India, the Islamic Republic of Iran and the Philippines, all because of poorly designed and constructed dwellings in earthquake-prone areas. Owing to economic and population pressure, increasing numbers of people are living in volcanic danger zones. In addition to warning and evacuation, appropriate structural measures such as lava flow channels, have helped reduce the damage to property, particularly in Japan. Losses due to landslides have been successfully reduced in Hong Kong, China by monitoring hazard-prone areas and undertaking appropriate structural and other preparedness measures.

In parts of the region there is still a need for preparation or review of earthquake-resistant design codes for buildings and other engineering structures and for their enforcement, as well as the undertaking of proper arrangements for the infrastructure to be able to deal with natural hazards and natural disasters.

c. Disaster management framework

Most countries of the region have enacted legislation which provides the necessary controls and responsibilities to cope with disaster situations. These laws permit the relevant authorities to govern the long-term requirements of disaster prevention and the short-term needs of disaster preparedness. Although statutory controls to govern the relevant aspects of community planning and development, including zoning, subdivision controls and environmental issues, which pertain to disaster prevention are available, many governments are reluctant to invoke them. Several governments have appointed a central organization to coordinate the disaster mitigation activities of the various government bodies and other interested groups, so that a comprehensive approach may be adopted. In certain countries, some of the organizations were established on an *ad-hoc* basis only when a natural disaster had occurred or was expected to happen. It is only the more developed countries of the region that have cohesive institutional arrangements in place.

Most governments have upgraded their civil defense capability for the rescue of people from endangered areas, through the mobilization of armed forces or the organization of the local community in response to threats of disaster through cooperative activities involving volunteers. A number of countries have introduced programmes to provide information and educate the public on hazard situations.

In a large part of the region it is now recognized that the initial and most vital response to a disaster must be at the local level and that the community must be well informed about disaster-preparedness measures and be alert at the time of disaster. Fostering disaster awareness in the general population, starting with the individual, is essential in reducing casualties. In order to promote community involvement in disaster prevention and preparedness, community awareness programmes and educational programmes on warning systems and other aspects of disaster preparedness are being developed and implemented, and committees that would include representatives of non-governmental organizations and the public are being established at the local level, to monitor and guide disaster-relief operations.

Many countries have appointed a national IDNDR committee or a central organization to coordinate the disaster mitigation activities of government bodies and other groups. These organizations are of interdisciplinary nature responsible for natural disaster reduction in some countries and areas of the region. In parallel, most countries of the region have enacted legislation providing necessary controls and responsibilities to cope with disaster situations and have upgraded their civil defence capability for rescuing people from endangered areas. A number of countries have introduced programmes to provide information and educate the public on hazards. More importantly, almost all countries have accepted in principle the need to integrate disaster prevention and environmental protection strategies into their national development plans. Besides, there is a growing awareness at present of the importance and effectiveness of regional cooperation in disaster prevention and mitigation, particularly among neighbouring countries. The developing countries of the region are also supported by bilateral assistance from various donors and from United Nations organizations and others such as the Asian Development Bank and the World Bank.

2. Structural measures for water-related disaster management

As explained in the preceding section, a variety of both structural and non-structural measures is available for coping with disasters. As this regional consultation workshop will focus on effectiveness of warning systems, only brief discussion of the structural measures are given below for reference. It may be noted that most or all of these methods have been used in the countries of the Asian and Pacific region as part of their disaster mitigation programs. The extent to which individual countries have applied them, and the degree to which they have been successful, has been varied.

a. Cyclone management

Winds are a fundamental property of tropical cyclones, whilst flooding and storm surges may be a consequence of tropical cyclones. A variety of structural measures has been taken to protect lives and property against these effects. Many countries in the region have conducted research into the structural effects of tropical cyclone damage and have developed structural and building designs and special materials to suit such conditions. They have also now developed improved structural design guidelines and standards governing building construction in cyclone-prone areas. Cyclone shelters have also been adopted.

b. Flood management

Levees and floodwalls are commonly used in the region to confine floodwaters to the stream channel and a selected portion of the floodplain to protect the land area immediately behind them and are effective only against flood depths up to the chosen level for which they were designed. However, these measures may create a false sense of security about the degree of protection provided and floods exceeding the levels for which the levees and floodwalls are designed can cause disastrous losses of life and property.

Various types of channel modification are also used to improve the hydraulic conditions of watercourses or floodplains. Floodways are usually adopted to serve two functions in flood mitigation: to store a portion of the flood water to hence decrease the flow in the main channel below the diversion and to provide an additional outlet for water from upstream. Flood storage and retardation are measures adopted to involve the deliberate, controlled flooding of designated areas in order to minimize overall flood losses. In appropriate circumstances dams are constructed to create reservoirs which control major flood flows by temporarily storing flood waters and releasing them at a safe flow rate.

c. Water-induced land instability

There is a variety of structural or mechanical measures which are usually applied to reduce the potential for land instability in areas where occupation cannot be prohibited. These measures include the following: preventing or diverting runoff flows around critical sites; de-watering sites using drainage systems; planting trees or shrubs which remove sub-surface water by transpiration; planting deep-rooted vegetation to bind sub-soil material; underpinning foundations to stable rock; battering slopes to stable grades; and constructing retaining walls along the toes of critical slopes.

d. Drought management

There is a variety of structural measures which are adopted in the region to mitigate the effects of severe drought. These essentially revolve around the careful management and conservation of surface and groundwater water resources. They can be considered in two categories: large-scale measures and small scale or on-farm measures. Large-scale surface-water conservation measures revolve around the provision of large water storage reservoirs for the regulation of natural streamflow and the delivery of this water to critical areas, sometimes over considerable distances, through irrigation, stock or domestic water supply systems. The availability of suitable and economical sites for large dams is now limited and new sites need to be chosen with care. Unfortunate experiences with very large storages in many developing countries, particularly in tropical regions, have shown that they can have serious adverse environmental, social and economic consequences and they need to be planned and designed with very considerable care. Efficient utilization of available damsites becomes increasingly important.

Unfortunate experience in many countries, where large-scale irrigation districts have been developed on semi-arid lands on the flood plains of major rivers, has been the development of salinity and water-logging in irrigated soils. In some cases, this has led to the total devastation of irrigated land and made it unsuitable for any form of agricultural activity. Within the Asian and Pacific region, it has occurred extensively in Australia, China, India, Pakistan and Thailand. To avoid the possibility of future degradation from this cause, new irrigation areas need to be carefully sited and selected on the basis of the soil type, the nature of the underlying strata, the quality of the irrigation water to be used, and the ability to provide an adequate drainage and disposal system.

In the Asian and Pacific region, groundwater is used extensively for irrigation, domestic and stock water supply purposes. Groundwater required careful management if it is to be available in adequate quantity and quality on a long-term basis, and particularly through prolonged drought conditions. There are some structural devices that have been used to improve the availability of groundwater supplies.

On the small of farm-level scale, a variety of solutions is also available. In arid areas with intermittent rainfall, or on higher rainfall areas with marked seasonal rainfall patterns, the construction of appropriately designed and sited surface reservoirs is a common practice.

3. Non-structural measures

The vulnerability of land and property to natural disasters can be reduced by structural works. The potential impact of these events can be further reduced by the imposition of land use controls, designed to manage land degradation and minimize exposure to the risk of disasters which cannot be avoided. To achieve this objective, legislative controls which empower the relevant government authorities to direct land use planning policies and practices related to watershed management need to be adopted and implemented. Whilst most of these measures have been introduced by individual countries within the Asian and Pacific region, they have not always be adopted along with a comprehensive range of structural measures in an integrated and coordinated fashion.

The various categories of non-structural controls available for disaster management and mitigation comprise the following: legislative and regulatory measures for controlling land occupancy, structural standards and emergency policies and services; land-use zoning; warning systems; emergency agencies, facilities and equipment; evacuation and flood relief services; and community education. Experience showed that all of these activities must be provided for in an integrated and coordinated fashion and supported by appropriate legislative requirements and administrative arrangements if they are to be successful. Of these devices, all are essential but perhaps the most likely to contribute most to overall regional and local disaster protection and preparedness is the technique of land use control, effected through land zoning plans and regulations.

Carefully prepared zoning plans are the basis for effective land use control. A variety of modern techniques, including remote sensing, satellite imagery, global positioning equipment and geographical information systems (GIS) has been adopted to provide effective tools for the preparation of basic topographical and geographical information. Geographical information systems utilize geographical data and information with respect to three components: spatial data, which pertain to the locational aspects of geographical features, along with their spatial dimensions; attribute data, which pertain to the description, measurement and classification of geographical features; and time, which is particularly important in natural hazard assessment because of the rapidity with which geographical features may alter during the occurrence of disaster events. The collection of such data has been greatly facilitated by the availability of various kinds of remote sensing systems. Its incorporation into a computer-compatible format, and its ability to be manipulated within the computer for rapid data analysis, classification and presentation, has been further facilitated by the ready availability of digital mapping devices and software programmes, which allow the ready transformation of analogue data from maps or remote sensing images into computer-usable format.

There is also a number of non-structural techniques available for drought mitigation. These include a variety of farming and stock management measures, as well as a variety of government policy, legislative, administrative and fiscal measures.

At the farm level, effective drought management procedures may include the following: conservation farming practices designed to improve the infiltration and retention of soil moisture; pasture improvement; the application of fodder conservation techniques; the management of stocking rates to avoid overgrazing and fodder shortage; and the introduction of more drought-resistant plant and livestock varieties.

At the government level, effect drought management practices may include the following: the provision of drought-relief funding; the use of taxation relief and other fiscal measures including long-term, low-interest rate loans to encourage conservation farming, good stock management practices and water conservation; the organization and coordination of government agencies for the provision of drought relief and assistance in drought management; the development and implementation of advisory and extension services to educate and assist the farming community; and the development, in association with other nations when appropriate, for research into the factors causing drought conditions, the forecasting of drought events and the operation of drought warning systems.

4. Geology-related management measures

On the subject of geology-related hazards, although extremely important and often crucial, few new developments were reported. Some of the following findings were mainly based on material already available at UNESCAP.

Earthquakes, landslides and mudflows are the principal geology-related hazards in *China*, prompting both structural and non-structural measures for natural disaster reduction. Since its establishment in 1989, the Chinese National Committee for IDNDR has been responsible for inter-departmental coordination, compiling 28 ministries, commissions and administrations. This led *inter alia* to the China National Plan for Disaster Reduction, the China Centre for Disaster Reduction and many relevant projects and programmes.

Although the territory is not immune to seismic hazards, landslides are by far the most common geology-related hazard in *Hong Kong, China*, with over the years, numerous casualties and considerable property damage in this densely populated, largely urbanized area. The authorities responded with short-term measures in the form of emergency slope repairs after failure, and long-term measures like systematic upgrading work for slopes as well as detailed investigations to learn more about the cause of the landslides. The Hong Kong Contingency Plan for Natural Disasters stipulates the functions and responsibilities of Government departments and other bodies in the event of a natural disaster, with each department having its own set of operational instructions, which are regularly reviewed and updated. Public awareness is kept at a high level by a variety of leaflets, brochures, posters and publicity messages on radio, television, the newspapers, the Internet, etc. Frequent meetings with property managers, insurance brokers, etc. are held to promote the incorporation of geohazard information in planning and decision making. The authorities have established legal frameworks for the implementation of disaster mitigation measures such as land-use planning and building codes.

Despite having been hit by a number of serious earthquakes during the Decade, causing severe damage and thousands of casualties, response measures in *India* appear to have been limited to post-earthquake damage surveys and preparation of seismotectonic surveys, the results of which serve as input to various institutions. Landslide hazard zonation maps are prepared for different landslide-prone areas and recommendations for countermeasures are made to road construction departments. Following the 1995 inaugural session of the ESCAP Forum on Urban Geology in Asia and the Pacific (FUGAP) in Calcutta, the Geological Survey of India (GSI) initiated a programme of geodata collection for the Calcutta Metropolitan Development Authority (CMDA), for the purpose of planning new urban development areas in a responsible manner. Upon its successful completion, this activity was expanded to include the whole of West Bengal, funded by the State Government. The GSI is currently conducting an advertising campaign throughout the country, which has resulted in several State Governments expressing interest in funding similar projects on their soil, in order to also reap the benefits of professional advice on local, including hazardous geological conditions that could affect their development as well as their contingency plans.

Although no major geology-related disasters in *Japan* were reported since the 1995 Kobe earthquake, information on seismic activity and tsunami warnings were issued, including a Warning Statement by the Prime Minister based on information provided by the Japan Meteorological Agency. The Disaster Countermeasures Act and the Large-scale Earthquake Countermeasures Act designate which agencies are responsible at national and local levels. The Disaster Prevention Research Institute of Kyoto University is conducting research on the prevention and reduction of natural disasters. The National Land Agency has jurisdiction over the Act on Special Measures for Active Volcanoes, and has been responsible for the planning and underlying policies of the Volcanic Disaster Countermeasures. Among the precautionary measures taken are the improvements of roads and port facilities for rapid evacuation in case of an imminent volcanic disaster. Shelters against ashfall and volcanic bombs have been built, communication networks improved and evacuation drills conducted. Projects to protect or rehabilitate production from agriculture and fisheries are under way, and staff and equipment for clean-up procedures and health checks are in place. At the same time, geophysical observation systems have been tested and

improved for volcanic eruption prediction, using tilt meters, extension/contraction measuring equipment, magnetometry as well as optical camera observation stations.

Partly in response to a number of catastrophic landslides, *Malaysia* established a National Disaster Management and Relief Committee at Federal, State and local levels. A National Hazard Action Plan was established, a Special Malaysia Disaster Assistance and Rescue Team was formed and a Policy and Mechanism of National Disaster Management and Relief was formulated (National Security Council Directive No.20). Courses on geology-related hazards were incorporated in the curricula of local universities, and to inform the public, a pamphlet on earthquake and related hazards was distributed. But perhaps most importantly, geology-related hazards are now routinely incorporated in town and country planning as well as environmental impact assessments.

Although *Myanmar* is part of a well-known earthquake belt, only landslides were reported among its recent geology-related disasters. A small-scale map of earthquake-prone areas was prepared and Myanmar joined the ASEAN seismology project ASNET-RESED. The Department of Meteorology and Hydrology is now establishing a nation-wide seismological network to monitor earthquakes and more accurately locate epicentres. A legal framework is in place for the regulation of land-use planning and the enforcement of building codes, with input from the Department of Geological Surveys and Mineral Exploration (DGSE), but budget constraints have so far precluded the preparation of geology-related hazard zonation maps at scales appropriate for use in urban planning and disaster management.

In response to the 1997 earthquake in *Pakistan*, it was suggested to enhance the awareness of the public of seismicity, followed by stricter enforcement of certain measures, such as building codes. So far, very few geology-related hazard maps have been produced, although this situation is reportedly improving.

Among the many natural hazards affecting the *Philippines*, the geology-related ones such as earthquakes and volcanic eruptions are numerous and well documented, resulting in frequent catastrophic events. The recent disasters have had an effect on institutional development programmes to enable disaster management agencies to respond effectively to emergencies. These included improvement of disaster management planning, updating of hazard maps, etc. At the national level, it was decided to develop hazard maps as a standard information tool to enable local governments to assess the vulnerabilities of their particular areas to such hazards. The National Disaster Cooperation Council was instrumental in improving the national statute on disaster management, incorporating all developments and lessons learnt from the past.

Although no recent major geology-related disasters in the *Republic of Korea* were reported, the Korea Meteorological Administration (KMA) has been involved in earthquake monitoring and the issuing of tsunami warnings. The KMA is the competent authority of the UNESCO International Coordination Group for the Tsunami Warning System (ITSU) and has proposed to establish a regional tsunami warning centre for the seas and coastal areas of the Far East. A Fund for National Disaster Countermeasures to the amount of US \$78 million has been allocated to 245 local authorities, including 15 cities, to be spent exclusively in case of a disaster.

Among the geology-related hazards reported by *Thailand* in order of importance are land subsidence, karst collapse, coastal erosion and earthquakes, although the latter are a rare phenomenon. Natural hazard maps are recognized as a principal tool for convincing the authorities to pay more attention to disaster reduction, although reportedly neither existing national development plans nor current risk assessment reflect the concerns of IDNDR. The Department of Mineral Resources (DMR) is conducting a Thai-German Technical Cooperation Project jointly with the German Geological Survey (BGR) entitled Environmental Geology for Regional Planning, which is producing geology-derived thematic maps of an area surrounding the city of Chiang Mai in the North of Thailand. The maps are incorporated in an operational GIS, for which the staff has been trained under the same project. This combined field-work and computer-processing capability provides the DMR with the opportunity to become a key operator in geology-related natural hazard mapping and risk assessment, and thus generate potentially huge savings for the local community as well as the Government.

The often major earthquakes that affect *Turkey* have so far resulted in attempts at stricter enforcement of building codes and a determination to re-evaluate these codes, but also in further steps necessary to improve urban development planning, building supervision as well as legislation. Other initiatives were the preparation of avalanche hazard zonation maps and training of personnel at the General Directorate of Disaster Affairs. Further achievements were the updating of the old (1975) version of the Building Seismic Design Code and the preparation of a probabilistic seismic zones map of Turkey to replace the 1972 version. Public awareness was fostered by means of television spots and pamphlets aimed at the school-going part of the population, and posters showing proper construction methods for self-builders in rural areas. The General Directorate of Disaster Affairs has successfully lobbied the media to repeat the message that natural disaster losses in Turkey are largely avoidable. Among the regional cooperative activities on natural disaster preparedness and loss reduction in which the country is involved, is the Cooperative Programme for Seismic Risk Reduction in the Mediterranean Region (SEISMED).

Although the country is prone to seismic hazard, landslides and mudflows were reportedly the only recent geology-related causes of natural disasters in *Viet Nam*. Geology-derived thematic maps, including geohazard maps are being produced under the nation-wide Urban Geology Programme 1993-2000 touched upon later on in this paper.

5. Regional cooperation programmes

From the experience of regional cooperation under the framework of UNESCAP, it was found that there has been a growing recognition in the region of the significant benefits of disaster prevention and mitigation, rather than *ad hoc* relief reduction activities. Some countries had a long-established framework for responding to the disaster mitigation requirements of the country. Others had either strengthened their institutional mechanisms or were in the process of overhauling them.

The development and use of radar for forecasting and measuring rainfall events and the increased number of telemetric rainfall stations in some countries had increased their capability for the rapid collection and processing of precipitation data and the forecasting of floods. There was still considerable variation among countries of the region with regard to the availability and reliability of equipment needed for effective cyclone and flood forecasting and warning. Prediction of drought had also become more reliable by taking into account such factors as the El Niño phenomenon and the undertaking of appropriate mitigation and preparedness measures.

It was determined that each country needed to improve the quality of forecasts and warnings in relation to water-related natural hazards and to increase the lead time of warnings, to enable areas likely to be affected to make adequate advance preparations. The need for emphasis to be given to the improvement of communication links for the transmission of basic data and providing related warning information about natural hazards was seen to be a priority issue.

Risk assessment and mapping had not been undertaken by most of the countries of the region. There was a need for comprehensive vulnerability analysis to be undertaken for disaster-prone areas, incorporating information about past disaster events, the socio-economic conditions of the population living in the affected area, and inventories of major structures liable to damage. Risk assessment and hazard mapping would then be used to delineate areas vulnerable to natural hazards and determine the frequency, intensity, impact, return period and other data in relation to each category of hazard.

With regional cooperation, substantial progress had been achieved in meteorological forecasting and warning of tropical cyclones, and the capability to forecast floods had improved considerably through the individual efforts of various countries, with assistance from the support given by UNESCAP, the World Meteorological Organization (WMO), UNDP and other organizations. Useful programmes and the capability to forecast tropical cyclones and floods had improved considerably through the establishment of the Typhoon Committee and the Panel on Tropical Cyclones as well as the Mekong River Commission. These first two subregional bodies had cooperated in the forecasting and warning of cyclones, information

exchange, provision of training and other forms of activity relating to the reduction of the impact of water-related natural disasters, as briefly discussed below.

a. Example of the Typhoon Committee

The Typhoon Committee was established by the participating countries under the auspices of ESCAP and WMO and has been functioning and holding annual sessions since 1968. The Typhoon Committee covered a wide range of activities on cyclone-related disaster reduction for which several important initiatives were launched under its framework, particularly those aiming at improving cyclone and flood forecasts. Among the initiatives undertaken, the two most important ones were the Typhoon Operational Experiment (TOPEX) programme and the SPECTRUM (Special Experiment Concerning Typhoon Recurvature and Unusual Movement) which laid down important infrastructure and established human resources and facilities for subsequent contribution to disaster prevention and preparedness. It may be noted that the objective of TOPEX was to carry out, through international co-operation in the prompt and reliable collection and exchange of observational data, an operational test of the functioning of the various systems used for cyclone analysis, forecasting and warning. TOPEX consisted of three components the meteorological hydrological and warning dissemination and information exchange components. TOPEX was an exercise that tested the effectiveness of the totality of the system built up over more than a decade for flood warnings, cyclone warnings and dissemination of information to the public. For flood loss prevention, the Committee had carried out the following activities:

- (i) evaluation of the established system for forecasting and warning of the hydrological effects of floods and/or storm surges by comparison of their outputs with actual observed data in the fields;
- (ii) identification of simple deterministic forecasting models used by, or available to services in the cyclone area, selection of specific models for application to each designated area and comparison of the models' results in real-time forecasting operational mode;
- (iii) evaluation of separate and/or combined hydrological effects of cyclones, particularly river and storm surge flooding, and thereby determination of associated flood risk.

In parallel, other regular activities have been in operation include:

- (i) operation, maintenance and improvement of existing flood forecasting and warning systems;
- (ii) establishment of flood forecasting and warning systems in other river basins;
- (iii) establishment of pilot areas for comprehensive flood loss prevention and management which included investigation, survey and study of the pilot areas, preparation of comprehensive plans for flood loss prevention and management within the context of overall water resources development of the pilot areas and implementation of selected aspects of the comprehensive plans by stages, if necessary.

In terms of activities for disaster preparedness, the Committee provided assistance in establishment of appropriate national organizations at all levels, and in formulation of plans; improvement of facilities and services for emergency communications; improvement of effectiveness of warnings and community reaction; training in disaster preparedness; improvement of techniques for assessment and reporting of damage and consequent needs; preparation and implementation of pilot projects for pre-disaster planning, including analysis of hazards and resources at all levels, and case studies on such plans and their effectiveness in practice; and development of measures to reduce damage associated with storm surge.

The advent of IDNDR has strengthened the cooperation among the Committee members and also helped enhance awareness on the importance of natural disaster reduction. The membership of the Committee continued to increase from 7 to lately 14, consisting of the Governments of Cambodia, China, Democratic People's Republic of Korea, Japan, Lao People's Democratic Republic, Malaysia, Macau, Philippines, Republic of Korea, Singapore, Thailand, United States, Viet Nam and Hong Kong, China.

b. Example of the WMO/ESCAP Panel on Tropical Cyclones

In parallel with the operations of the Typhoon Committee, the Panel on Tropical Cyclones was also established under the auspices of WMO and ESCAP to promote measures to improve tropical cyclone warning systems in the Bay of Bengal and the Arabian Sea. The Panel aims to direct their common endeavours towards successful implementation of a comprehensive cyclone operational plan to facilitate the most effective tropical cyclone warning system for the region with existing facilities.

As part of the common endeavour, the Panel adopted a comprehensive cyclone operational plan for this subregion. The basic purpose of the operational plan was to facilitate the most effective tropical cyclone warning system for the region with existing facilities. In doing so the plan defined the sharing of responsibilities among Panel countries for the various segments of the system and records the co-ordination and co-operation achieved. The plan recorded the agreed arrangements for standardization of operational procedures, efficient exchange of various data related to tropical cyclone warnings, issue of cyclone advisories from a central location having the required facilities for this purpose, archival of data and issue of a tropical weather outlook for the benefit of the region.

The operational plan contains an explicit formulation of the procedures adopted in the Bay of Bengal and Arabian Sea region for the preparation, distribution and exchange of information and warnings pertaining to tropical cyclones. Experience has shown that it is of great advantage to have an explicit statement of the regional procedures to be followed in the event of a cyclone, and this document is designed to serve as a valuable source of information always available for reference by the forecaster and other users, particularly under operational conditions.

A technical plan aiming at the development and improvement of the cyclone warning system of the region has been drawn up by the Panel. Implementation of some items under the technical plan would lead to a strengthening of the operational plan. The operational plan is evolutionary in nature. It is intended that the text of the plan be updated or revised from time to time by the Panel and that each item of information given in the annexes to the plan be kept up to date by the member country concerned. The plan included a hydrological programme comprising two main components:

- (i) hydrological network and flood forecasting systems, and
- (ii) storm surge project.

Cooperation among the members continues to be strengthened with the implementation of these components in addition to work on meteorology. An important point to note in this respect is that through the implementation of the plan, the exchange of hydrological data among the member countries for flood warnings has been greatly improved.

c. Example on geology-related disaster preparedness

In the 21st Century, many millions of people will have to be housed and employed in urban areas that have yet to be planned and constructed. The availability of pertinent geological information such as geology-related hazard maps should enable planners and decision makers to make the right choices and locate new urban areas away from hazard zones. This is among the most cost-effective measures aimed at natural disaster reduction. It follows, that national geological survey departments should be requested and funded to collect relevant information and present this to planners, disaster managers and other decision makers in central governments and/or local authorities on a regular basis and in a format that is readily understandable to non-geologists. To this end, UNESCAP actively promoted the integration of geological information in urban planning and decision making during the past two decades.

To date, a number of member countries have indeed established their own “geology for planning” programmes, supported either by national funding or from bilateral sources. Notable examples are the initiatives taken by the Ministry of Land and Resources of China, the Geological Survey of India and the Department of Geology and Mineral Resources of Viet Nam. Still, the availability of relevant information is not enough. In this connection, the Forum on Urban Geology in Asia and the Pacific (FUGAP) was

established in 1995 in Calcutta, India. Since then, the Forum continued to hold its regular meetings to exchange information and experiences on integration of geological information into urban development for better disaster management. From the past several years of collaboration, it was recognized that FUGAP was an effective means of increasing awareness among both geoscientists and planners of the benefits of knowledge of geological conditions in (urban) planning and decision making, including geology-related hazard management. To be even more effective, the Forum agreed that similar meetings should be hosted by the participating member countries and should bring together planners, geologists, local authorities and media representatives.

6. Community awareness and participation

In many countries of the region it was recognized that the initial and most vital response to a disaster must be at the local level and that the community must be well informed about disaster-preparedness measures and be alert in the time of disaster. It was considered essential that the building of disaster awareness in the general population, starting with the individual, was essential in reducing casualties. In order to promote community involvement in disaster prevention and preparedness, community awareness programmes and educational programmes relating to warning systems and other aspects of disaster preparedness were developed and implemented, and committees that included representatives of non-governmental organizations and the public were established at the local level to monitor and guide disaster-relief operations.

a. Participation: a learning process

Participation in the development process and disaster mitigation and preparedness is in fact a learning process: to learn about each stakeholder's aspirations, expectations and new perceptions of the situation. It is also a process of learning from other practitioners, especially those in developing countries. It is therefore important in the participatory planning and management process to establish mechanisms to institutionalize the past lessons and new trends. Such mechanisms would need to pay attention not only to the technical aspects of the development process, but also to tools and practices along with the circumstances that are conducive to improvement in participation efficiency. It is also important to note that the strong desire of learning to enhance active participation and the commitment to sustain that desire would have much-farther-reaching effects on the promotion of participation than any models or techniques on participation.

b. Participation: a concept changing strategic planning paradigms

It is commonly recognized that national socio-economic development is a complex process, of which flood mitigation and preparedness efforts form a part. In this process, it is increasingly accepted that the development of strategic approaches for the integration of measures on flood management is necessary. Strategic planning has long been popular in business management, but its use in the public sector has only emerged since the 1980s, when strategic planning and management was introduced in several European countries, e.g. bringing salmon back to the Rhine River. Subsequently, several countries have since introduced strategic planning and management into national development and administration, notably the United States, when its Congress adopted the Government Performance and Results Act (in 1993) to lay down details for strategic planning and management.

In fact, the need of participation in strategic planning and management in the private sector has actually changed the paradigms for strategic planning from a purely top-down approach to interactive approaches, including bottom-up processes⁶. Originally, military leaders used the term 'strategic planning' to differentiate it from 'tactical planning'. In those contexts, tactical planning implies short-term measures;

⁶ Ti Le-Huu, "Brief history of strategic planning in the public sector and trends of strategic planning and management of water resources", presentation at the Subregional Workshops on Capacity-Building on Strategic Planning and Management of Water Resources for Asia and the Pacific, ESCAP, July-October 2002.

strategic planning, long-term measures. Since then, strategic planning has often meant long-term framework to guide short-term development. In the 1970s, with the emergence of the energy crisis, the concept of efficiency was adopted and a strategy was defined as a coherent set of actions required to achieve established goals in an efficient manner. In the 1980s, with the increased acceptance of the open-market economy concept, strategic planning requires establishment of vision on development and adoption of the participatory approach at every step of the planning and management process. It was during this period that application of strategic planning and management was started by the public sector. Lately, with the growing concern for sustainable development and equitable and fair social systems, it is increasingly accepted that strategic planning and management requires (1) to be guided by shared vision, (2) community participation at every step of the planning and management process, and (3) a sound system of decision-making for good governance.

Participation should therefore be recognized as a powerful tool. With a clear vision of leadership and an effective framework for good governance, public participation will be active and will prosper.

c. *Participation: a challenge towards a common goal for civilized societies*

In view of the above lessons, not only should participation be viewed as a tool or an approach for effective development or flood mitigation and preparedness, but effective participation must also be considered as a goal in itself. All communities would thrive towards prosperity and be safe from disasters, including floods. Towards such prosperous and safe societies, it is indispensable that people be responsible in their contributions to the common goals and shared visions of their respective societies. These are civilized societies, and application of participatory planning and management should bear that goal in mind.

III. INTEGRATION OF EARLY WARNING SYSTEMS INTO NATIONAL DEVELOPMENT PLANNING PROCESS

1. Integration of disaster management measures

In the light of the many major disasters experienced throughout the Region during the past decade, it would be desirable to review the disaster management practices of the member countries. The experiences gained should be used as a basis to assist further evolution of disaster management practices, especially in those areas where implementation practices could be improved.

Wholesale changes do not appear warranted but adjustments to the existing approach would achieve:

- further mitigation of disaster damage to existing development;
- control over the future growth of potential disaster losses.

To achieve these objectives, there appears to be a case for the adoption of a system which could be effectively implemented as part of the member's disaster strategies.

After examining the available information on the status of disaster management in the Asian and Pacific region, it is apparent that many of the member countries are yet to adopt an integrated approach for disaster management. The preferred disaster management system should integrate the following elements:

- the individual management measures;
- the roles and responsibilities of all stakeholders;
- the disaster management plan and the disaster emergency plan;
- the resource management considerations and programmes;
- where applicable, the concept of comprehensive land-use planning based on total watershed management principles.

The objectives of the overall management system should ensure that:

- disaster management matters are dealt with having regard to community safety, health and welfare requirements;
- public information is freely available on the likely extent and nature of possible future hazards;
- all reasonable measures are taken to alleviate the hazard and damage potential to existing properties at risk, and there is no significant growth in future hazard and damage potential resulting from new developments;
- appropriate forecasting and warning systems exist, and emergency services and government assistance are available in the event of future disasters;
- the disaster management system is managed having regard to social and economic costs and benefits to individuals as well as the community at large.

An integrated approach is required to bring together these diverse issues, which are usually fragmented over a number of different authorities. This can be achieved through greater cooperation amongst the agencies, authorities and individuals involved in all aspects of disaster prevention and preparedness. The extent to which the integrated approach can be achieved relies on a number of factors, including the management of natural resources and the strength of existing legislation. As a general principle however, the overall coordination of disaster management plans should be vested in a single organization, preferably operating at the national level, which assumes responsibility for legal, administrative and financial matters relating to the management of natural disasters.

The ultimate goals of integrated disaster management should be to limit the hazards and damages to socially acceptable levels, to promote environmental enhancement and to provide disaster warning, response, evacuation and recovery from the onset to the aftermath of the disaster.

2. Education, training and information sharing

The adoption of such a system could however pose a problem for some countries, which may lack the specialist technical skills needed to develop a comprehensive management plan and the capacity to implement the resulting prevention and preparedness measures. These problems could be addressed by the provision of specialist professional support and training for their agencies and institutions and financial subsidies from national governments and donor countries.

The disaster management process requires an ongoing commitment to the education and training of disaster managers by the various tiers of government and professional bodies. The exchange of information regarding difficulties, problems and solutions and the results of research is essential for improved disaster management. This can be fostered by the free flow of information at the local and international levels through formal agreement, workshops and conferences.

There is a number of significant advantages to be gained by adopting a national and international approach to water-related disaster management. This approach would lead to a better and more efficient use of the resources of each nation and the region. Disaster management principles have developed to a different degree and in different ways in the various ESCAP countries. Considerable cost savings and efficiencies could be achieved through the sharing of information and experiences in the coordination of disaster management research activities among the various countries. This form of cooperation would promote a consistent approach to disaster management policies and techniques, leading to better disaster management practices, and would help to reduce each country's exposure to the risk of future disasters. Moreover, wider cooperation amongst neighbouring countries would facilitate the development of a regional data base of disaster related information throughout the region. This information should promote a better and more efficient allocation of resources to disaster management both within individual countries and across the region.

3. Examples in the region

a. Perspectives of early warning systems in Japan

(I) Geographical context

Japan is one of the rare countries in the world with mountainous land, divided into various mountain ranges, almost fully covered with forests, and volcanic zones crossed by countless rivers making its topography more complex. Flatland occupies only 30% of the total land, 70% of the flatland is used as arable land and the rest consists of build-up areas, wetlands and sandy shores. 50% of the population and 75% of properties are concentrated in the alluvial plains consisting only 10% of the total land. Unlike the standard topographical characteristics of most rivers in the world (e.g. Thames River in London), most of the Japanese flatlands are lower than the water level in major rivers (Fig. 1). Steep slopes compared to other rivers worldwide as shown in Fig. 2 also characterize these rivers. This particular characteristic increases the vulnerability of Japanese rivers to instant great flooding and rapid decrease of water level during and after torrential rains respectively. For instance, during period of floods the water volume in Tone River may rise as high as 100 times above its normal flow, while the flow at the

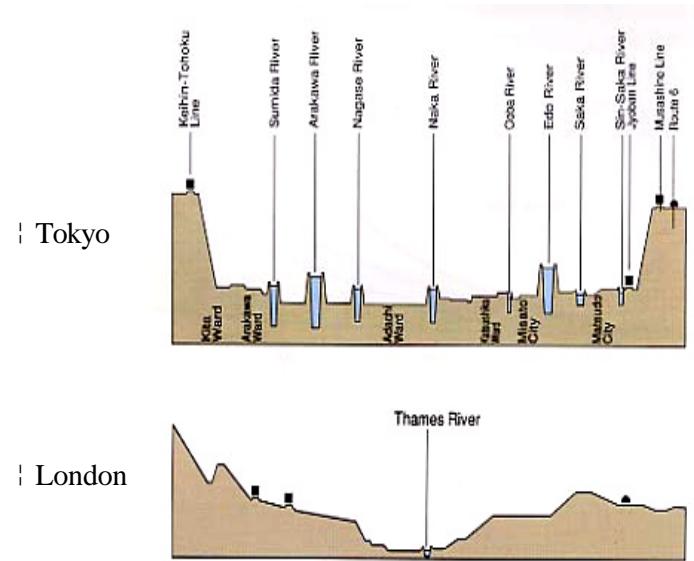


Fig. 1. Topographical characteristics of Japanese rivers.

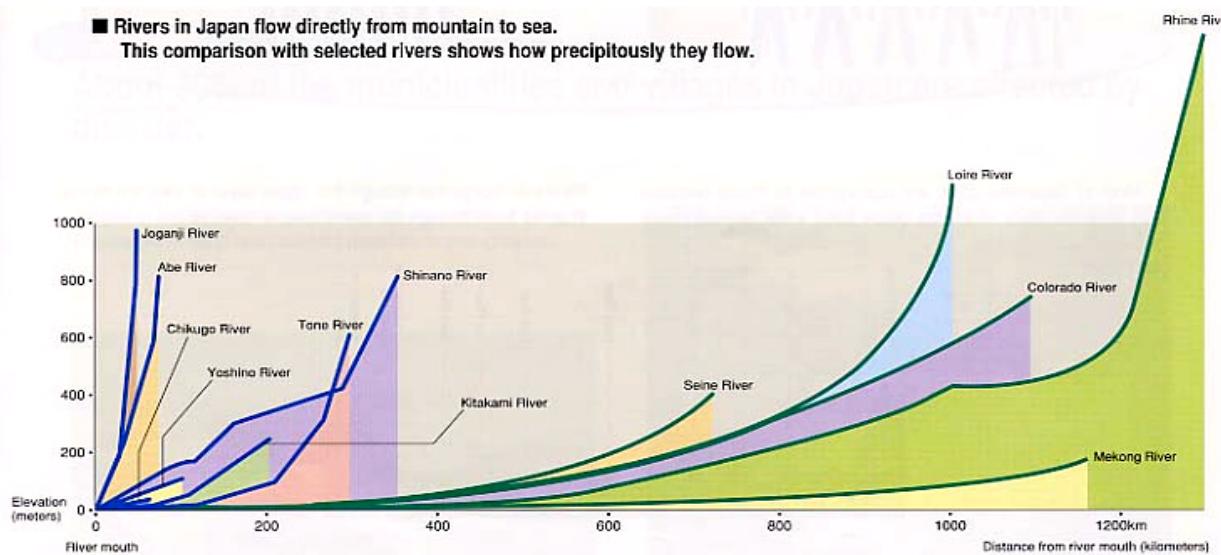


Fig. 2. Comparison of the characteristics of the river slopes in Japan with selected rivers in the world.

Donau and Mississippi Rivers may only increase for about 3 and 4 times above their normal levels respectively. It is important to emphasize that the main annual precipitation of approximately 1700mm, which is about twofold the world's average of 970mm, is concentrated especially during the rainy and cyclone seasons. This concentration of heavy rains represents the major cause of frequent floods and sediment disasters observed in all over Japan (Fig. 3).

Despite the many years of flood control efforts that have resulted in reducing the total inundated area, threat to flood damages is still striking many regions in Japan due to the continuous concentration of population and properties in the flood prone area.

(2) Natural disaster management and development of early warning systems in Japan

From the mid 1940's and 1950's, Japanese archipelago was annually struck by large-scale cyclones such as the typhoon Kathleen of 1947. The damages were enormous due to the devastating state of land caused by destructive forest lumbering and stagnation of flood control projects during the World War II. This flood disaster drew the attention on the importance of flood warning. As a result, the flood warning liaison meetings were installed on key rivers since 1948. The "Flood Fighting Act", proclaimed in July 1949, provided a base for flood prevention and mitigation of damages caused by floods. Consequently, "Meteorological Business Law", regulating operations on meteorology including observation, warning and information disclosure was endorsed in June 1952.

The primary amendment of "Flood Fighting Act" in 1955 made flood warning a part of flood prevention activities and defined that its implementation should be realized with initiatives of the Minister of Construction and the Central Meteorological Observatory. Furthermore, the act made the Minister of Construction or Prefectural Governors responsible for flood prevention warning. Flood prevention administrators prepared flood prevention bodies and fire fighting organizations to be ready for intervention. The above initiatives provided the base of current flood warning systems in Japan.

Although no amendments have been brought about to the institutional system of flood fighting act, the damage frequency caused by dike breaks or inundation at large rivers has been declining due to steady implementation of river improvement projects in recent years. However, for medium and small sized rivers, related closely to people's lives, the number of damages caused by dike breaks for example remains still high. However the concentration of population and properties, due to the growing urbanization in the alluvial plains is leading to higher figure in property damage and loss.

In recent years, drastic rainfall of more than 100mm is no longer rare with the rapid increase in torrential rain of more than 75mm on hourly basis (Fig. 4). Such torrential rains, usually exceeding the current urban drainage capacity causes frequent occurrence of flood damage of urban type such as the inundation of underground space, and paralyzed lifelines due to inundation at medium and small sized rivers (e.g. Fukuoka flood damage in 1999 and Tokai torrential rain in 2000). The damages caused by concentrated heavy rain is not restricted to urban areas, frequent sediment disasters have also been observed in many areas along the mountainous districts (e.g. in Hiroshima City and Kure City after a torrential rain in 1999).

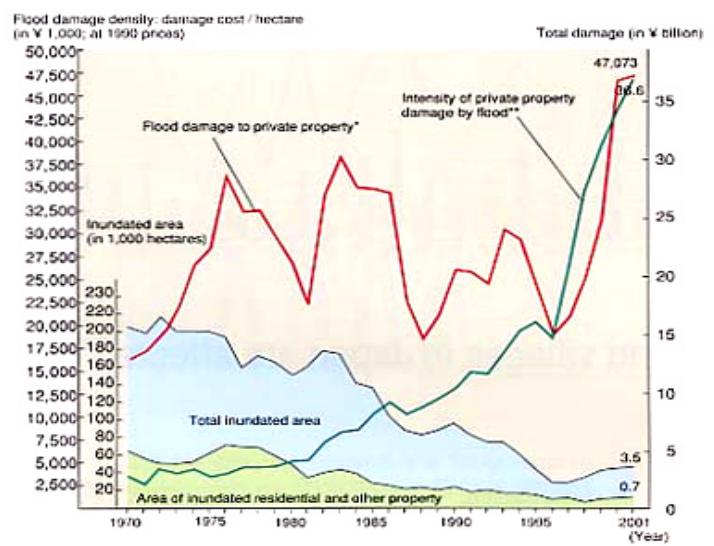


Fig.3. Change in intensity of private property damages by flood

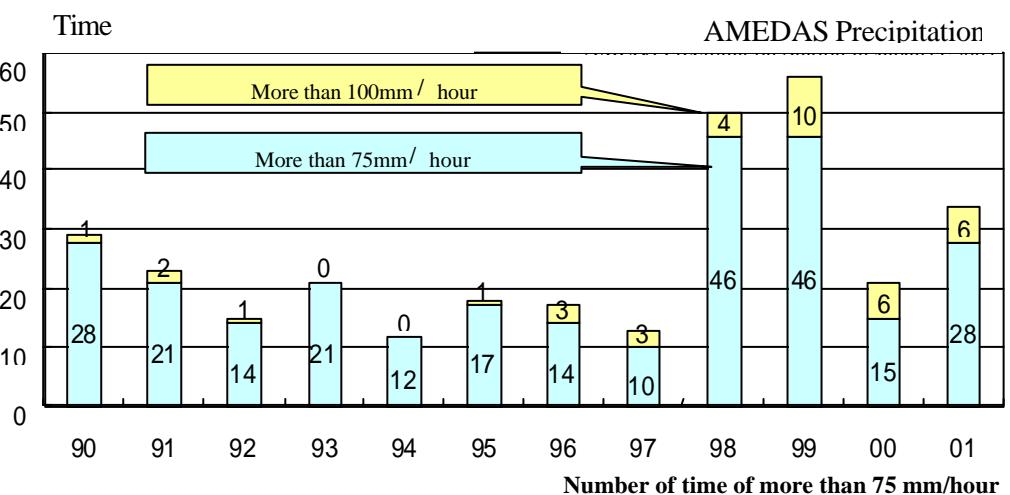


Fig.4. Frequency occurrence of torrential rain

Under the new Japanese perspective for water-related disaster prevention, it is admitted that hard measures such as river improvement is not sufficient to address the current situation, and more focus is placed on soft measures including maintenance of evacuation systems and information dispatching. To support such new approach in flood measures, the sediment disaster prevention act was proclaimed in 2000 and the flood fighting act was revised in 2001.

Further details on important achievements of flood forecasting and warning in Japan are given in Annex 2 and also in a separate paper to be circulated at the Workshop.

b. *Drought Early Warning Systems in India*⁷

(1) *Drought Impacts and Coping Mechanisms*

Recurring drought-induced food insecurity is a serious development issue in arid, semi-arid and dry sub-humid areas of India. Drought is a slow onset natural hazard and offers opportunity and time to mitigate its impact. The transition from meteorological to hydrological and then agricultural drought constitutes its basic consequences. The deterioration of drought conditions over a period of time leads to famine, the ultimate consequence of drought.

The household response pattern to food crisis generally involves a succession of stages along a continuum of “coping” that runs from risk minimization, absorption and risk-taking to survive. Risk minimization and absorption strategies are those through which households preserve their productive assets to recover in another season after the drought. These are reversible strategies. “Risk taking to survive” strategies are those when a household’s position is so desperate that they sacrifice future security for present survival. These are all less reversible strategies, which leave households worse than before.

(2) *Identification of Indicators for Early Warning*

Various indicators appear broadly, sequentially reflecting the extent and depth of household stresses. Agro-climatic indicators are leading indicators that reflect the initial signs of risk minimization strategies adopted by households. Market socioeconomic indicators are concurrent and denote risk absorption strategies. Late anthropometric indicators reflect survival symptoms.

The objective of designing an early warning system is to keep track of leading indicators to get ample lead-time to intervene at the drought onset phase itself, compared to early warning systems designed to capture concurrent or late indicators. However, most interventions based on late indicators force governments to adopt a crisis management approach to dealing with drought-induced food insecurity stresses. There are many deficiencies in this approach; and in the long-run it does not reduce vulnerability to drought.

(3) *Evolving Early Warning Systems in India*

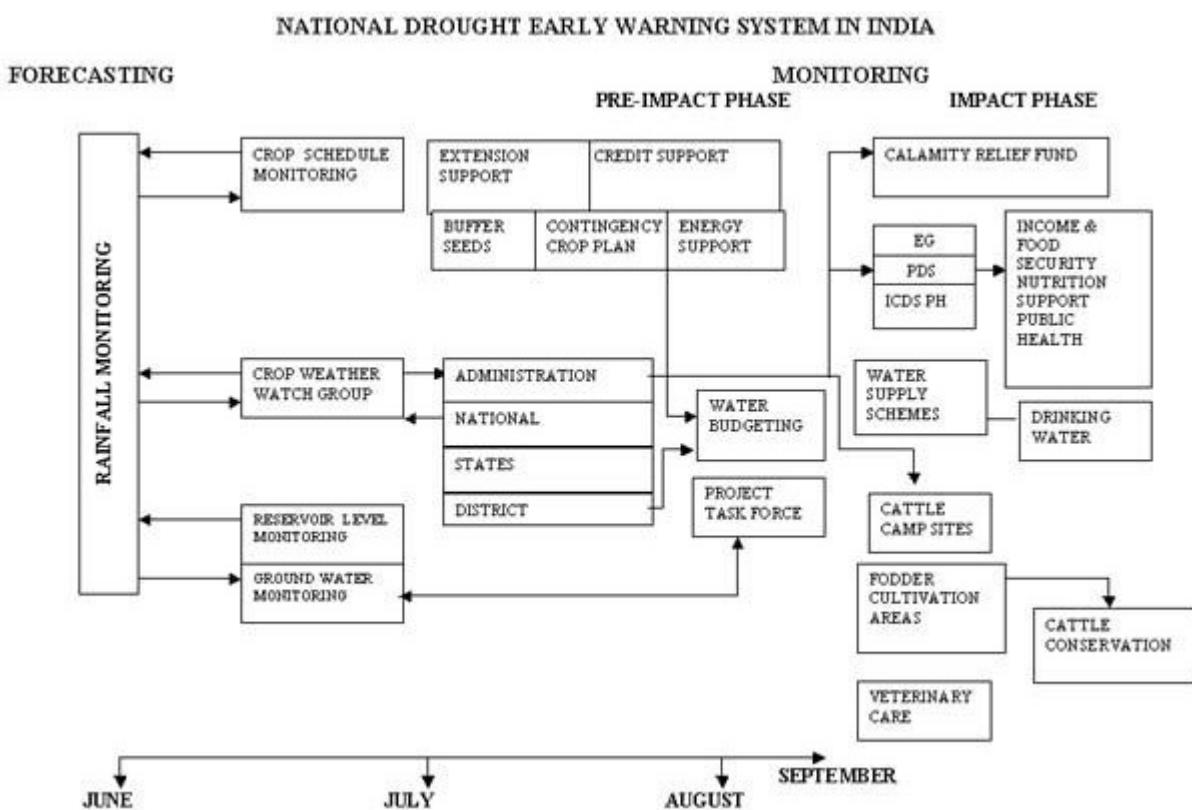
Studies of Indian drought management approaches in the last hundred years reveal that India relied too heavily on crisis management approaches before and during the pre-independence era (before 1947). However, after the mid-sixties, based on the experience of tackling the 1966 drought-induced food crisis, serious efforts were made to replace ad hoc crisis management relief interventions with an anticipatory drought management approach.

A drought management approach differs from a relief approach with regard to objectives, reliance on early warning indicators and timing of public intervention. Thus the drought management approach aims at ensuring food production, relying on leading agro-climatic indicators, like rainfall, water level in reservoirs and progress of cropping pattern, to detect early signs of a developing drought situation.

⁷ Extracted from a paper by A R Subbiah, who is presently working at ADPC as a Program Manager, Extreme Climate Events and Climate Forecasting Applications in Bangladesh. He can be contacted at subbiah@ait.ac.th

A national-level crop weather watch group (drought forecasting) was established in 1979 to monitor the impact of the monsoon on crop conditions and to suggest corrective measures to minimize crop losses. The National Early Warning System has an integrated drought forecasting and monitoring system at present. It is structured to provide operational and retrospective intelligence for constant information update based on feedback on the impact of intervention measures. While a drought relief approach with a monitoring system enabled the government to intervene only in the months of November- December after the kharif harvest (summer crops) was over, the drought management approach with a forecasting system enabled the government to intervene in July-August (within the monsoon season). This early warning system offered a lead-time of five months before the appearance of distress indicators in December-January. This was evident in the management of a severe multi-year drought during 1985-87.

There are two components of the National Early Warning System: drought forecasting and drought monitoring. The drought forecasting function is carried out by the Inter-Ministerial National Crop Weather Watch Group (CWWG), which meets during the monsoon period from June to September. It monitors the impact of the monsoon on agricultural operations and also suggests corrective measures to minimize any possible adverse impact of aberrant monsoon conditions on crop production as per the standing contingency crop plan. In case the CWWG anticipates widespread adverse seasonal conditions, it sends out a report. This triggers the operationalization of an emergency contingency action plan for drought management, which envisages institutional arrangements and operating procedures for the drought monitoring system.



c. *El Niño-related Droughts in the Philippines: Impacts and Mitigation Efforts*⁸

The El Niño Southern Oscillation (ENSO) is now a well-developed model to link regional climate extremes to fluctuations in sea surface temperatures (SSTs) over the central and eastern equatorial Pacific Ocean. The SST anomalies in the warm pool area of the Pacific have a strong correlation with climatic variability in the Philippines, particularly during the northeast monsoon season (October to March). An El Niño event is manifested in the Philippine local climate by drier than normal weather conditions that can last for one or more seasons, causing dry spells or even drought in many parts of the country. Weak monsoon

⁸ extracted from a paper by Dr Aida Jose is Chief, Climatology Branch, PAGASA, cab@philonline.com.ph

activity, early termination of the rainy season and suppressed tropical cyclone activity near the country are other manifestations.

(1) *El Niño Impacts*

During El Niño, the consistently low annual rainfall over river basins leads to a significant decrease in the water inflows in major reservoirs. Worsening decreases in inflow result in curtailment in the domestic and irrigation water supply, thus causing water rationing in residential areas and reduction in irrigated farmlands. The agricultural sector is affected by widespread water shortages induced by El Niño, which is also when crop production damage is highest, not only in upland and rainfed areas, but also in lowland irrigated areas.

The high temperature and rapid evaporation of surface water during El Niño create unfavorable conditions for marine fishes. Production losses are caused by drying of fish ponds, shorter production cycles, stunted fish growth, and fish mortalities from stress, poor water quality and disease. El Niño-related drought events are also associated with indirect environmental effects. Due to the long dry spell that moves into the otherwise wet season, forest fire destruction has steadily increased in recent years.

(2) *Mitigation Efforts*

In past El Niño episodes, the Philippine government responded with each agency formulating its own action plan. This fragmented approach did not curb the effects as evidenced by the extensive losses incurred. It was recognized that the effects on agriculture, environment, domestic water supply, health and energy are inherently interrelated and called for a more coordinated approach.

The government response during the most recent El Niño (1997-98) was initiated by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA, Weather Bureau) through the issuance of a monthly weather outlook by the National ENSO Early Warning and Monitoring System (NEEWMS). The NEEWMS is an enhancement of PAGASA's Drought Early Warning and Monitoring System (DEWMS), the objective of which is to provide timely assessments of weather conditions and other information needed by various end-users, particularly policy decision-makers and those concerned with crisis management. The assessment of various weather elements and developments in the global climate system make possible the early detection of an impending extreme climate event. Advisories are immediately issued to the public to mitigate adverse impacts even before an event occurs.

PAGASA's early warning of the 1997-98 El Niño episode alerted the public and government to better prepare them for the anticipated effects. Before the warming event reached its peak, the Office of the President of the Philippines issued a memorandum creating the Task Force on the El Niño Phenomenon, an interagency body of representatives of sectors that might be affected by El Niño. Together, the eleven members formulated action plans for strategic programs to help the populace cope with the phenomenon and to minimize its disastrous effects. A Comprehensive Action Plan included government interventions to forewarn, educate and direct both government and private sector mitigation efforts. This was complemented by intensive tri-media information and education campaigns. The comprehensive program centered on measures that affected the agriculture, domestic water supply and environment sectors. The program likewise called for an analysis of past El Niño episodes and identification of potential crisis areas.

IV. NEED ASSESSMENT AND PRIORITY ACTIONS

1. Perception of water-related disaster management process

In a recent regional survey conducted by UNESCAP for the Typhoon Committee and the Panel on Tropical Cyclones, disaster prevention and preparedness, including warning systems would need to consider as a process. For an effective integration of cyclone-related disaster prevention and preparedness into the economic and social development process, a DPP process would need to include core, strategic and complementary elements to ensure continuity and consistency of DPP. The process was considered to be

composed of three key components: management, capacity building and institutional development processes.

There appeared to be a consensus among the responses to focus the DPP process towards better preparedness as reflected in the priority as follows:

1. Management process (with data collection and forecasting and warnings as the priority core activities),
2. Capacity building process (with forecasting technology and basic communication network as priority core activities) and
3. Institutional development process (with inter-sectoral coordination as the top core function).

This perception reflects not only the priority of the countries but also in view of the comparative and strategic advantage of the respective subregional cooperation bodies.

a. Management process

In the management process, most of the responses emphasized the need to strengthen the development of policies and strategies on DPP as well as financial resources mobilization. Apart these priority activities, more than 50 per cent of the responses identified the need to enhance public information and education and strengthen structural measures as part of the core activities of DPP. In summary, the core priority needs include:

1. Data collection and forecasting and warning
2. Policies and strategies development and financial resources mobilization
3. Awareness and communications and structural measures

In terms of strategic activities, the responses identified the needs to enhance public information and education, awareness and communication, capacity building and financial resources mobilization as well as to strengthen structural measures on DPP. More than 50 per cent of the responses also identified improvement in the non-structural measures, risk management and institutional coordination as strategic activities. More 50 per cent of the responses also indicated that most of the activities identified in the management process were being implemented, except integrated basin management and risk management.

In terms of weighed average of overall priority, the responses attached top priority to the following activities:

- (1) Data collection and financial resource mobilization
- (2) Forecasting and warning
- (3) Policies and strategies
- (4) Non-structural, and
- (5) Structural measures.

b. Capacity building process

In terms of the capacity building process, the priority core activities were found to be similar to those in the management process, with emphasis on forecasting technology and communication network. More than 50 per cent of the responses identified the following activities as core activities: basic network development, core human resources development, advanced monitoring technology, advanced communication systems and telemetering system. In summary, the core activities for capacity building process include the following:

1. Forecasting technology and basic communication network
2. Basic network development, core human resources development, advanced monitoring technology, advanced communication systems and telemetering system.

In terms of strategic activities, the priority was given to advanced training in forecasting, decision support system and GIS-related development. More than half of the responses also identified several

activities as strategic: human resources development strategies, advanced monitoring, advanced communication, telemetering and risk management technology. More than half of the responses are implementing the following capacity building activities: forecasting technology, basic communication network, basic network development, basic water resources investigation, and telemetering system. It is quite surprising that only the basic network development activity was accorded top priority by more than half of the responses. The lack of consensus on this may reflect different perception on the priority needs in each Member. It may be noted that nearly half of the responses indicated that a core human resources development was under consideration and not yet implemented. This probably an area to more effective cooperation among the participating members for DPP.

c. Institutional development process

In terms of institutional development process, most of the responses identified "inter-sectoral coordination" to be a core activity to which there appeared to be a consensus. In weighed average, the activities were ranked as followed:

- (1) Inter-sectoral coordination,
- (2) Inter-provincial coordination,
- (3) International cooperation and
- (4) Decentralization.

2. Geology-related disaster mitigation

a. Early warning and management of geology-related hazards

Greater emphasis should be placed on expanding observational and monitoring systems, especially in areas of the region where data are scarce. There is still a need to establish or upgrade observational equipment and networks to monitor the hazard properly and to disseminate warnings quickly through an efficient warning system. To help improve this, reliable feedback information should be collected on warning performance, public response and damage caused by natural disasters.

Existing seismic data acquisition networks in the countries vulnerable to earthquakes should be updated and improved. Certain areas in the region still lack seismic data acquisition systems. Research in earthquake prediction should continue. Regional cooperation could take the form of establishing a network of observation stations for hydrogeodynamic (HGD) monitoring using widely spaced water-wells covering large areas (around 1,500 x 2,000 km, possibly spanning several countries) surrounding earthquake-prone areas (belts with active seismic faults). Such a network based on international collaboration could prove an invaluable component in a regional warning system for earthquakes with the potential to extend the forewarning to about three to four months before the violent seismic stress release at the epicentre.

Volcanic eruptions usually provide clear warnings, but this does not apply to earthquakes. However, electronic sensors placed virtually on active earthquake faults, hundreds of kilometres away, may provide an extremely short but vital "early warning" of an imminent earthquake, as has been the case not long ago in Mexico City, where an automatic earthquake alert sounded 72 seconds prior to the arrival of the tremor, just enough to enable the population to vacate their houses, schools and other buildings, thus helping to minimize the number of casualties (INCEDE Newsletter, vol.4, no.2, 1995).

In the same context, Japanese and American seismologists have kept a close watch on the major interplate faults, but in fact many if not most earthquakes occur on "intra-plate" faults that are merely associated with the major faults. So, early warning in those cases would only be attained if all these secondary faults were under constant electronic monitoring also.

Space technologies such as remote sensing, satellite communication and global positioning systems have been widely used in monitoring the occurrence of different types of natural disasters and in evaluating the losses and the impact. Even if many natural disasters cannot be averted, their impact can be reduced

through timely warning and by evacuation measures being taken. Space-borne techniques can play a significant role here.

It is worth noting the extreme precision with which vertical shifts in ground elevation (ground swell) can now be detected by remote sensing techniques like synthetic aperture radar (reportedly down to a millimetre). Like HGD monitoring, this capability may be used to detect stress/strain build-up associated with imminent earthquakes. Hence, studying "current" tremors and their strain phenomena immediately before these events may reveal which pattern is most indicative of imminent earthquakes.

For tsunamis, early warning networks in the Pacific should be completed. There is also a need to improve monitoring of major sources of volcanic risks not sufficiently covered so far and for the preparation of an inventory of volcanic tsunami risks in the region.

b. Strengthening institutional frameworks for disaster mitigation

Perhaps the most important need at the national level is to strengthen or develop capacity to undertake national disaster mitigation strategies. After assessing and mapping natural hazards experienced in the past and analyzing possible future risks and their potential social and economic effects, the adequacy of the existing disaster reduction measures can be evaluated.

Before this can truly be claimed for geology-related disasters, national, provincial and urban geological survey departments should be strengthened to enable them to devote a significant portion of their human and financial resources to the collection, interpretation and presentation of data on geohazards for the use of planners, disaster managers and other decision makers.

The Forum on Urban Geology in Asia and the Pacific (FUGAP) has proved to be particularly useful for the exchange of experiences between professionals and decision makers involved in geology-related disaster reduction. With support from the donor community, the Forum is expected to convene on an annual basis and serve as a source of inspiration and motivation for its participating members.

Institutional arrangements could be established for the exchange of information among neighbouring countries on all phases of a disaster on a continuous basis. Developed countries may consider devoting a percentage of their training efforts to assisting least developed and developing countries, with emphasis on in-country training. The countries should consider undertaking research and studies on various aspects of natural disasters and their reduction, with international assistance if required.

V. CONCLUSIONS AND RECOMMENDATIONS

Disasters identified in the recent surveys by UNESCAP included floods, cyclones, earthquakes, drought, tornado, debris flow including landslide and mudflow, hailstorms, surge, tsunami and regional haze. The most common disaster experienced practically in all the responding countries was floods. These disasters resulted in loss of lives, serious economic damages and severe impacts on the social conditions. Although the severity of these events, floods or earthquakes or drought and others, is different from one country to another, the most critical year appeared to be 1998, followed by 2000, 1997 and 1995. In 1998 alone, the economic damage in these countries was estimated to be over US\$23 billion (US\$20 billion in China, \$1 billion in Bangladesh, \$1 billion in Republic of Korea, several hundred millions in India and Viet Nam.)

Because of the continuing rapid population growth in the countries of Asia and the Pacific, people, mostly the poor, are being forced to settle at squatter areas in large cities, usually inhabiting low-lying flood-prone areas, unstable hillsides or other disaster-prone marginal areas owing to the high cost of suitable alternative locations and the extremely high cost of new infrastructure and services. In consequence, the number of persons vulnerable to natural hazards is increasing rapidly.

The principal reasons for the continuing increase in the loss levels caused by natural disasters include (i) the continuing growth of the population, (ii) the increase in building density by the growing concentration of people and the economic assets in urban areas, and (iii) a constant migration of people to

coastal areas that are generally more highly exposed to natural disasters. The development of industry in regions that are subject to natural hazards, without appropriate protective measures being taken, is another reason for the growing increase in the loss levels caused by natural disasters.

Natural hazards cause a high number of lives to be lost, but relatively small property losses, in the least developed and developing countries. In the relatively developed countries, on the other hand, where disaster prevention and mitigation measures are adequately established, the loss of lives is relatively small but the damage to property can be high. Losses may of course vary considerably within a given country.

China's structure of land use dictates the disaster composition of the country. In terms of the geographical extent of vulnerability, the bulk of farmland and pastures are the main areas threatened by natural hazards. In the event of a disaster, therefore, peasants and herdsmen are affected the most, and in case of a destructive disaster, thousands upon thousands of households may be adversely affected. However, in terms of total losses, those resulting from disasters in urban areas will usually be much heavier.

The effect of natural hazards on the loss of human lives is directly related to the poverty levels in a given country. National and regional efforts for natural disaster reduction should therefore be closely linked with poverty alleviation and economic and social development activities.

Another factor that exacerbates the effects of natural hazards is the environmental degradation taking place in many countries of the region. The damage caused by natural hazards is higher in countries where environmental degradation is rampant. Deforestation, erosion, overgrazing, overcultivation and incorrect agricultural practices and the degradation of natural buffers amplify the effects of natural hazards.

Various measures were adopted by the respective authorities in all the countries and areas to reduce impacts of disasters and to prevent future disasters. They were structural and non-structural measures, short-term and long-term plans or strategies, legislative measures, institutional development and publicity programmes. The non-structural measures included land-use guidelines and zoning, disaster-prone and risk mapping, disaster-proofing measures and warning systems. The wide spectrum of measures taken by the members and associate members of ESCAP indicates a diversity in the experiences and offers good opportunities for information exchange. All the responses believed that further improvement in disaster preparedness and prevention is possible, particularly with respect to warning systems, public awareness in risk management, institutional capacity building, disaster management planning and coordination, construction of structures, application of advance technology, better land-use planning and enforcement of zoning, and most importantly political commitment.

a. National achievements

All the responses confirmed accessibility to national and local warning systems and some indicated their established link with regional and international mechanisms, such as the Typhoon Committee, the Panel on Tropical Cyclones and WMO programmes. Many countries confirmed availability of various components for risk management but only two indicated existence of comprehensive risk assessment at the national level, one at selected localities. Various stages of preparation of structured mitigation plans were indicated in the responses and six countries indicated availability of national structured mitigation plans and one with provincial and local plans.

Various reasons were identified as obstacles by the countries or areas in their efforts to implement the Decade targets. Among these, the lack of financial resources was the prevailing reason, followed by the lack of technical capacities, particularly advance technology and modern equipment, and weakness in coordination and institutional arrangements. Other reasons included that the Decade targets were too ambitious and prioritization would be necessary; lack of strong political commitments; vigorous international efforts would be required.

In order to generate public awareness, various programmes have been adopted at the national, provincial and local levels. Media and publications are widely accepted. Short-term programmes in the form of workshops or seminars and formal education curriculums have been adopted for training purposes.

Involvement of decision-makers and major groups to ensure their support and participation in disaster reduction programme was achieved through various established mechanisms and procedures as indicated in almost all the responses. These mechanisms included those responsible for information dissemination, for disaster management planning, policy formulation, strategy implementation and legislative bodies. Collaboration with other sectors was indicated through the established guidelines and mechanisms (Malaysia), information dissemination (Thailand, Hong Kong, China), development plan (Bangladesh), and projects (China, Singapore, Turkey). Seven responses indicated the benefits of the international arena provided by the IDNDR for information exchange. Others did not get direct access to the arena.

All in all, the Governments of the Region have responded positively to the objectives of the International Decade for Natural Disaster Reduction and made significant advances in their abilities to cope with such disasters, particularly in the area of disaster preparedness. They have also confirmed the need to continue strengthening existing frameworks, to upgrade activities in some priority areas, and above all, to focus upon a fully integrated approach to disaster management issues and to involve the entire community. They have also confirmed the need to continue fostering national and international cooperation for advancement of disaster management in the Region by way of technology transfer and the encouragement of financial support from the more developed countries.

b. Regional/subregional achievements

Important achievements from subregional cooperation were identified in several responses in the field of tropical cyclones, floods, tsunami forecasting as well as training in disaster preparedness and management. Reference was made to the work undertaken within the framework of the Typhoon Committee, the ESCAP/WMO Panel on Tropical Cyclones, UNESCO Tsunami Warning System, Eastern Asia Natural Hazards Mapping Project, the Asian Disaster Preparedness Centre, Asian Centre for Disaster Reduction in Tokyo and lately the ASEAN Regional Haze Task Force (1998). Apart from these mechanisms mentioned in the responses, several regional and international mechanisms were also cited at the IDNDR-ESCAP Regional Meeting for Asia such as the Mekong River Commission, the ESCAP Forum on Urban Geology in Asia and the Pacific (FUGAP), and the RADIUS Programme. It was believed that regional mechanisms are needed to continue promoting exchange of information and experience. Regional cooperation was also expected to make important contribution to disaster reduction in general and enhancement of resource mobilization, communication networks, warning systems, improvement in forecasting techniques and training.

c. Future requirements and priority areas of cooperation

Most responses indicated their agreement to the importance of the criteria identified in the questionnaire as requirements for successful implementation of disaster reduction activities in the 21st century. However, the order of priority of the elements of requirements was different among the responses. Policy and budgetary commitment and public awareness together with strong linkage to economic and social development programmes were commonly accepted as top priority. Other priority included international cooperation, information dissemination, strengthening of local authorities, and network building. Several responses provided additional criteria as necessary conditions for the future operations:

- (1) Proper land-use planning and to apply integrated approach in management of resources.
- (2) Establishment of programmes to promote awareness on disaster prevention and reduction. Cooperation can be made on specific tasks, projects, information dissemination and warning systems, and post disaster management assessment.
- (3) Latest technology be used.
- (4) Improvement of sophisticated numerical models to predict local heavy rainfalls; to simulate tsunami generation and propagation; to improve seismic observation network.
- (5) To support science and technology transfer. Establish central data and information systems in the region. Cross-sectoral coordination.

- (6) A strong bonding mechanism among the IDNDR related international programs and national projects is required.
- (7) Build up effective networking at national, regional and global levels.
- (8) TCDC be improved; lack of financial resources; common policy needed in the region; regional network and communication be upgraded.
- (9) More budget resources; strengthening legal system.

All the responses reaffirmed the needs and importance of international cooperation for future disaster reduction activities. Among the top priorities identified by most of the responses were technical assistance, financial support and technology transfer. With regards to technical cooperation, most of the responses attached priority to subregional cooperation on early warning systems, communication networks and disaster preparedness.

With regard to future programmes and measures, several responses identified the need to put in place national disaster reduction programmes (or plans or strategies) with political commitment, proper institutional framework for coordination and resources availability. Several responses confirmed the need to establish or strengthen regional/subregional mechanisms for better interaction, information exchange, forecasting systems, enhanced public awareness and technology transfer. One country suggested that "IDNDR be changed to International Committee on Natural Disaster Reduction (ICNDR) to keep up the momentum at international and national levels."

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ANNEX I. CATEGORIES OF NATURAL DISASTERS

1. Water-related natural disasters

Water-related natural disasters in the form of tropical cyclones, floods, landslides and mud flows are periodical occurrences in the majority of the countries of the Asian and Pacific region. In many places land degradation, the consequence of poor land management, has served to aggravate the seriousness of such disasters.

The available data indicate that whilst not all the ESCAP countries are affected by tropical cyclones, very few of them are free from damaging flood events. These data also indicate that whilst tropical cyclones and associated storm surges are likely to cause the highest numbers of fatalities, floods are the most frequently occurring disaster events and the ones which cause the greatest total amount of damage. Tsunamis are also the cause of substantial destruction in coastal regions. Elsewhere, landslides and mud flows following very heavy rainfalls may cause considerable damage in both urban and rural communities. Droughts are a frequently occurring natural disaster in many countries, impacting particularly upon rural communities. Land degradation may exacerbate and prolong the adverse consequences of such events.

a. *Tropical cyclones*

Tropical cyclones occur more frequently in Asia, and particularly in the Northwest Pacific, than in any other part of the world. In the Asian and Pacific region, the most frequent source for the formation of tropical cyclones is just east of the Philippines, where the main tropical cyclone season extends from July to October and the frequency of occurrence in those months is about five cyclones per month.

Tropical cyclones spawned in this region generally track westward and may later turn north-west, first affecting the Philippines and then moving on to the Asia mainland or recurring north-eastward towards Japan. Those tropical cyclones which move westward across Indochina tend to lose their intensity after crossing the coastline. They may redevelop, however, over the Bay of Bengal and continue to move westwards over India or recurve northwards towards Bangladesh or Myanmar.

In the Bay of Bengal, in addition to those cyclones originating in the Northwest Pacific, tropical cyclones commonly develop over the southern section of the Bay and move in either a westerly or northerly direction to affect India, Bangladesh or Myanmar. These cyclones are more likely to occur before April/May or after October/November and may be accompanied by storm surges.

Some tropical disturbances track across India or develop over the Arabian Sea and more towards Pakistan, Eastern Iran or the Sultanate of Oman. The occurrence of damaging tropical cyclones which affect these countries is infrequent.

Tropical cyclones originating within the Southern Hemisphere zone of the Asian and Pacific region have an extensive spawning area which includes the Indian Ocean, the Timor Sea, the Arafura Sea, the Gulf of Carpentaria, the Coral Sea and the South Pacific. Within this region, the frequency of occurrence of tropical cyclones is about half that which is experienced to the north of the Equator and the tropical cyclone season is restricted to the period December to April. These Southern Hemisphere disturbances tend to have more erratic tracks and slower travel speeds than those formed in the Northern Hemisphere, although their destructive effects may be just as severe.

b. *Floods*

Within the Asian and Pacific region, the extent and cost of disastrous flooding has been intensifying as a consequence of increasing populations, denser occupancy of floodplains and other flood-prone areas, and the expansion of adverse forms of watershed land use. Within this region, floods are the most frequently occurring and the most destructive of all the forms of natural disaster which affect the area, although tropical cyclones have caused heavier loss of life. The most serious flooding experienced in the region comes from intense rainstorms associated with tropical cyclones or widespread and prolonged heavy rainfall associated

with monsoonal depressions. Cyclonic storms may occasionally produce more than 1000 mm of rainfall per day and monsoonal flood rains may persist for many days. The resulting floods may produce inundation over periods lasting from a few hours to three weeks or more, depending upon the size of the catchment and the characteristics of the river channel and its floodplain.

Within the Asian and Pacific region, riverine flooding is a common occurrence which involves substantial average annual flood damage costs. In this region, a very high proportion of the community in many countries occupies floodplain sites which experience frequent and devastating flooding. The most common cause of disastrous riverine flooding is prolonged intense rainfall, although in some parts of the region, in the Himalayas or at higher latitudes, snowmelt may be a contributing factor.

The most severe flooding experienced in the region is caused by very intense rainfall associated with major tropical cyclones, particularly where the influence of the cyclone extends over a considerable area. Intense long-duration rainfall associated with monsoonal depressions is also an important cause of serious riverine flooding. In the large river basins of the region, such as the Ganges, the Mekong and the Yangtze, flooding is usually seasonal and may last for many weeks. These basins are subject to continual rainfall during the wet season and exhibit a long high water period, with a comparatively slow rise and fall, during this season. Major flooding can result if intense storm rainfall occurs during such conditions. On smaller drainage basins, on rivers such as those of north China, Japan and the Republic of Korea which are subject to occasional tropical cyclones and intense convective storm activity, basin lag times are shorter and marked fluctuations of river level can occur during wet season conditions.

In the Asian and Pacific region, the most serious forms of coastal flooding may be due to storm surge, storm tides or tidal waves (tsunami). Within the Asian and Pacific region, many of the most severe disasters associated with tropical cyclones have involved storm surges. These phenomena are most severe in coastal regions within the tropical cyclone belt, although coastal flooding can also occur in extra-tropical and temperate regions. Countries/areas which are particularly susceptible to storm surge disaster include Australia, Bangladesh, China, the Philippines, the Republic of Korea, Thailand, the Pacific Island countries, Hong Kong, China. The northern sector of the Bay of Bengal, where the coast geometry exacerbates the phenomenon, is reported to be particularly at risk.

c. *Land instability*

The term “land instability” is used here to apply to those kinds of disaster which involve the sudden movement of masses of earth and rock material down slopes and hillsides, principally as a consequence of heavy and prolonged rainfall. Such disasters include landslides, earth slips, mud flows, talus slides and detritus flows and they are assumed to be associated with abnormal meteorological phenomena such as tropical cyclones, heavy thunderstorms, or intense and prolonged storm rainfall events associated with monsoonal fronts and extra-tropical cyclones. Land instability can also be initiated by earthquake action, which in some cases may aggravate the effects of rainfall saturation and gravity sliding.

In the Asian and Pacific region, water-based disasters due to land instability are of widespread occurrence and periodically lead to significant damage and loss of life. They are particularly prevalent within the tropical cyclone belt, on steep hillside and mountain country which has been cleared of native vegetation and developed intensively for agriculture or rural village settlement. In more temperate regions, land instability can also be a serious problem in mountainous areas where intense and prolonged rainfall events can occur. For example, landslides are a common occurrence in the Himalayas, whilst extensive land slip disasters are occasionally experienced in other countries, such as Thailand.

d. *Drought*

Drought might be briefly defined as a serious water shortage. This implies some specification of the amount of water required and the purpose for which it is to be used, both of which will determine whether a drought condition exists. What constitutes a drought for a given use in a given location may not be considered a drought elsewhere. By way of example, in Bali a drought is defined as a period of six days without rain,

whereas in Central Australia an annual rainfall total of less than 200 mm might be considered normal and a severe drought may have a duration of several years.

Because the nature and severity of a drought event is determined by weather conditions, it is difficult to predict its onset, its intensity or its likely duration. In the Asian and Pacific region, this is particularly the case in higher latitude, continental regions which are outside the Tropics and away from monsoonal, trade wind or other seasonal rain pattern influences. There is increasing evidence, however, that in those parts of the region lying around the western Pacific rim, the occurrence of severe drought is associated with the El Niño phenomenon. Drought is an intermittent problem in all the countries of the Asian and Pacific region, even including the Philippines, Indonesia and the islands of the South Pacific. Major drought disasters are experienced from time to time in Australia, India and Northern China, where the consequences of a drought event may be of very considerable significance to the national economy over a long period. Heavy loss of livestock, human disease and starvation, loss of wildlife and natural vegetation, and extensive and long-lasting land degradation, are all likely outcomes of drought disaster.

2. Geology-related natural disasters

a. *Earthquakes and tsunamis*

During the past 25 years, earthquakes have caused more than 1 million deaths worldwide. Seventy per cent of the earthquakes measuring seven or over on the Richter scale occurred in the Asian and Pacific region, at an average rate of 15 per year. The most devastating earthquake in the world in recent history, the Tangshan earthquake, which occurred in China on 28 July 1976, is reported to have claimed over 240,000 lives.

Tsunamis, the tidal waves generated mainly by earthquakes or other geological activity on the floor of the sea, are other seismic events that severely affect the nearby coastal areas and cause disasters. The famous Krakatau volcanic eruption of 1883 in Sunda Straits, Indonesia, generated a 35 metre high tsunami, causing the deaths of 36,000 people. The tsunami of 16/17 August 1976 caused the deaths of several thousand people in the Moro Gulf area of the Philippines. In July 1998, the 10-metre tsunami that hit Papua New Guinea took more than 2,000 lives in several coastal villages. Since it takes only a few minutes for a tsunami to travel from where it is generated to the nearby coastal areas, there is normally not enough time for adequate warning to be given. Tsunamis continue to affect some coastal areas of the region.

The 20 June 1990 earthquake in the northern part of Islamic Republic of Iran claimed 36,000 lives largely because of the collapse of dwellings. The country was again struck by an earthquake on 23 February 1993, measuring 5.8 on the Richter scale, with follow up shocks. However, this time the number of fatalities was limited to 9 persons, with 300 houses damaged. Another earthquake in May 1997, in Northern Iran killed over 1,500 people, injured 2300 and left 50,000 homeless. The February 1991 earthquake in Afghanistan claimed 545 lives. Again in May 1994, the northern part of Afghanistan experienced an earthquake, its epicentre in Uzbekistan, causing 160 deaths, 330 injured with 20,000 houses and 260 public buildings damaged or destroyed. The event of April 1998 however, was the most destructive so far in this Decade in Afghanistan. The earthquake of magnitude 6.1 affecting the Rustaq district in Takhar Province, about 50 km from the border with Tajikistan affected 24 villages with a total population of around 32,000 people. Some 17,600 lived in the nine most severely damaged villages. The death toll was 2,323 with 818 people injured, 8,094 houses destroyed and 3,083 livestock lost. The stricken area was extremely poor with almost no infrastructure, i.e., no surfaced roads, electric power or piped water. The quake of 21 March 1998 in the same region had reportedly not caused any casualties and resulted in minor damage to some buildings.

In May and August 1992, two powerful earthquakes had struck a remote and mountainous part of Kyrgyzstan, destroying 11,000 homes and damaging more than 18,000 others. As in the Islamic Republic of Iran, in Afghanistan and Kyrgyzstan the unsuitability of houses to withstand earthquakes experienced in these areas was the main cause of such large-scale destruction. In Kazakhstan, during the 1992-1993 period, three earthquakes were felt which killed two persons and caused a total damage of US\$ 1 million.

Nepal lies in a region of high seismic activity. Earthquakes with magnitudes of 5 to 8 on the Richter scale have been experienced throughout the country. Owing to the degradation of the hill slopes, seismic tremors may induce landslides. Such landslides often occur in the monsoon season following an earthquake in the previous year. About 50 to 60 per cent of India is vulnerable to seismic activities of varying intensity. The vulnerable areas are located mainly in the Himalayan regions of the country, and the Union Territory of the Andaman and Nicobar islands. However, the September 1993 earthquake struck Maharashtra State in Central West India, according to some accounts, nearly 12,000 persons were killed, 17,000 injured and 170,000 affected. It was the most devastating earthquake in half a century of the country, although it was not a particularly strong event. Another earthquake also struck Central India in May 1997, but fortunately not on such a devastating scale. Pakistan also experiences earthquakes, particularly in its northern regions. Bangladesh also senses tremors from time to time.

Thailand experienced some tremors causing slight damage, mostly in the western and northern areas with their epicentre locations near the northern borders or in neighbouring northern countries. Similarly, the Lao People's Democratic Republic and Viet Nam feel some earthquakes as well. In Viet Nam, the Red River Delta is the country's most seismically active area. Lying on a major geological fault, it has been shaken by 500 recorded earthquakes.

China has been suffering heavily from earthquakes. It has been estimated that since the beginning of this century, earthquakes in China claimed over 600,000 lives, accounting for 50 per cent of the global total during the same period. The February 1996 earthquake in Yunnan province killed over 320 persons and destroyed or damaged 1 million dwellings. In January 1998, another earthquake that struck northeastern China killed 70 persons and affected more than half a million people. In China, four fifths of its territorial area, 60 per cent of large cities and 70 per cent of megacities are located in seismic regions. In terms of magnitude, the western part of China is liable to be struck by stronger earthquakes than those striking the eastern part. However, the casualties and economic losses caused by earthquakes to the East, where the population and economic activities are concentrated, are higher than in the western part of China.

Japan is located in the Pacific seismic zone. While the Japanese islands and the surrounding continental shelves amount to only 0.1 per cent of the total area of the world, it has been estimated that the energy of the earthquakes emitted from that area is equivalent to about as much as 10 per cent of what the earth generates in total. In Japan, a great earthquake of Richter scale 8 recurs every ten years, and a large scale earthquake of magnitude 7 once a year. The 17 January 1995 earthquake of 7.2 degrees on the Richter scale, devastated the Kobe-Osaka region, one of the most densely populated areas in Japan, taking nearly 5,500 lives, injuring 37,000, totally or severely destroying over 200,000 houses and causing a total damage of at least US\$ 100 billion. Japan also frequently experiences tsunamis, and it has dealt quite successfully with the effects of tsunamis by improved tracking and warning of tsunamis generated at some distance and by the construction of proper protective works along the vulnerable stretches of its coasts. Nevertheless, the tsunami generated by an earthquake at sea claimed 230 lives and caused heavy damage to property, particularly in the northern island of Okushiri in July 1993. Off the North-West coast of Papua New Guinea, an earthquake of magnitude 7 occurred in July 1998, generating a 7 to 10-metre high tsunami which swept 50 km of coastline, killing more than 2,100 people with hundreds missing.

The Philippines lies between two of the world's major tectonic plates and can experience an average of five earthquakes a day, most of which are imperceptible. The earthquake on 16 July 1990 was one of the strongest and most destructive to have occurred in the country recently. The tremor had a magnitude of 7.7 on the Richter scale and affected an area of about 100,000 km² on the island of Luzon. A 125 km long, fairly continuous ground rupture was generated by the event. Liquefaction of water saturated sediments caused extensive damage to coastal areas and fluvial environs in central Luzon. Shaking of the ground by the tremor caused a large number of buildings, including a major hotel, to collapse or to be severely damaged. Ground movement also triggered shallow landslides in the mountainous regions of northern Luzon. As a result of the earthquake, several cities and towns received severe damage to their municipal buildings, markets, schools and housing. It claimed the lives of 1,666 persons, injured 3,561, and caused a total damage of nearly US\$ 1 billion. Another earthquake that hit the Mindoro island in November 1994 also

generated a tsunami of over 10 metres in height which killed 74 persons, injured 171, and affected over 50,000 families.

Tsunamis have also affected the coastal areas of the Philippines up to more than 4 metres above sea level. The coastal areas of Mindanao island facing the Celebes sea are particularly vulnerable. A tsunami originating off the coast of the Americas would reach the eastern coast of the Philippines in about 16 hours. From off the coast of Japan, it would reach the Philippines in about 3 hours. If it originated within the archipelago's seabed, the lead time would be about 16 minutes.

Indonesia is another country of the region, which is vulnerable to earthquakes and tsunamis. On 12 December 1992, an earthquake with a magnitude of 7.5 on the Richter scale occurred, followed by tsunamis, affecting mainly the Flores island. There were also several aftershocks. Nearly 2,000 people were killed and 90,000 rendered homeless. Another earthquake of 6.5 on the Richter scale shook the southern part of Sumatra island on 16 February 1994, which was also felt in Jakarta. Two hundred and seven people were killed, 464 severely injured and over 2,000 houses, 133 government buildings, 138 schools and 184 mosques were damaged. The total damage was estimated as US\$ 170 million. On 2 June 1994, an earthquake occurred south of Java that created tsunamis killing 222 persons, injuring 440, destroying over 1,350 houses and wrecked or damaged 768 fishing boats. A February 1996 earthquake killed over 100 persons and destroyed over 5,000 houses. This earthquake caused a tsunami that reached 7 metres in height which was responsible for a large part of the damages.

b. Volcanic eruptions

Some parts of Asia are frequently subject to severe volcanic eruptions. The countries that face the hazards of volcanic eruptions are Indonesia, Japan, and the Philippines. In Indonesia alone, there are 129 active volcanoes. Sixteen of these are located in the densely populated island of Java, which has an average of about 850 people per square kilometre. Nearly 3 million people live in the volcanic danger zones. Unlike earthquakes, the volcanic eruptions can be predicted well in advance and monitoring of volcanoes has been well established in the hazard-prone countries in the region, where timely warnings have helped save thousands of lives.

In the Philippines, 21 volcanoes are considered to be still active, having erupted within the last 600 years. In the twentieth century, eleven volcanoes recorded sixty-three eruptions. The eruptions of Mt. Pinatubo in Central Luzon, during the period 12-15 June 1991, and the subsequent effects of cyclones, heavy rainfall and lava flows resulted in extensive damage to public infrastructure and private property. The pyroclastic flows generated by the eruptions affected an area of over 120 sq. km, charred vegetation as far as 15 km from the source, and filled up drainage canals with pyroclastic material. The deposits of thick ashfall caused the collapse of roofs, blanketed rice fields with several centimetres of ash, clogged and damaged engines and machinery and caused some respiratory problems and eye discomfort. The rainfall during and after the ejection of pyroclastic material mobilized a part of these deposits, burying vast tracts of agricultural land and settlements under 1-5 m. thick layers of sediments, debris, and boulders. The devastation by lavas continued during the rainy seasons of 1991 and 1992. Eventually lavas covered an area of 270 square km.

In April 1991, prior to the major eruption, the Government of the Philippines had established a warning and emergency response system, after receiving a report from a resident of volcanic activity. In order to identify hazards that could arise if the volcano erupted, topographic map and air survey analysis, and field verification were conducted. Three major hazard areas were identified: pyroclastic flow, lava and ashfall, and corresponding hazard zonation maps were completed in May and immediately disseminated to local government officials of the provinces at risk and then a disaster information campaign for the residents was implemented. Nevertheless, 847 people were killed, 281 as a result of the eruption, 29 were victims of the lava, and 537 from exposure to diseases at the evacuation centres. Hundreds of thousand of people were displaced, 100,000 hectares of land damaged and close to one billion US dollars of damage was caused to the infrastructure.

In early November 1993, Mt. Pinatubo erupted again killing 11 villagers. In minutes, 90 per cent of the 400 houses of a nearby village had disappeared. The eruption dumped billions of tons of rocks and ash on Pinatubo's slopes. As heavy rains came, those deposits turned into ferocious rivers of mud that could wipe out everything in their path. Furthermore, lava flows from Mt. Pinatubo continued to claim lives and destroy property and infrastructure. The Mayon volcano, located in Southern Luzon, erupted twice on 2 February 1993, with one eruption lasting as long as 30 minutes. Some people caught working in their rice fields, died of severe burns after being enveloped by clouds of superheated steam, mixed with ash and debris. 77 lost their lives. The Mayon volcano has a history of eruptions every 8-10 years. It is still active. Another volcano, Taal, located near the capital city of Manila, took 190 lives in its 1965 eruption, and is still very active.

The 129 active volcanoes of Indonesia are distributed in a belt along the length of the archipelago. Advances in volcano monitoring and the issuing of timely warnings have reduced the fatalities significantly in recent decades. In the six major eruptions between 1980 and 1990 in Indonesia, 38 persons lost their lives. In previous eruptions of the same volcanoes, a total of 5,890 people had died. The 1919 eruption of the Kelud volcano killed 5,110 persons, the 1966 eruption took 210 lives, and in the 1990 eruption, total number of fatalities was reduced to 32. The November 1994 eruption of the Merapi volcano situated on the island of Java claimed 58 lives. The January 1997 eruption of the same volcano was much less harmful. The decrease in the number of victims, in spite of the constant increase of the population in surrounding areas, is a good indication of the successful implementation of volcanic hazard mitigation programmes in Indonesia.

Japan has at least 33 active vents. The Aso volcano on the Kyushu island, has one of the largest craters in the world. The Asawa on Honshu, since its violent eruption over 200 years ago, has been continuously active. There is another active volcano on Kyushu. Sakurajima near the city of Kagoshima has also been active recently. The 11 February 1990 eruption of Mt. Unzen-Fugendake near Nagasaki on the Kyushu island, was followed by pyroclastic flows on 3 June 1991, resulting in 43 killed/missing and 9 injured. Large quantities of volcanic deposits and rain have caused occasional debris flows. In 1993, major debris flows took place in the months of April, May and June. Over one thousand houses have been totally or partially destroyed. Mt. Fugendake still remains active.

ANNEX II. IMPORTANT ACHIEVEMENTS IN FLOOD FORECASTING IN JAPAN

1. Current state of flood forecasting

a. Necessity of Flood Forecasting

Flood control in Japan has developed to a great extent through consistent flood control activities since World War II and ongoing efforts have been made toward achieving complete flood control. However, there is no prospect of completing flood control plans entirely in the near future, not even for class A rivers.

A study of the Ministry of Land, Infrastructure and Transport (MLIT) shows that about 10% of urban areas across the country would suffer some degree of flood damages in the case of heavy rain with precipitation of 50 mm/hour, which is expected to occur once every 6 to 7 years. Flood forecasting is therefore indispensable for the residents of those areas as they would need to evacuate or take other measures to protect their lives and properties, if faced with a flood. However, no flood plan, even after completion, can guarantee complete safety against a flood. Once a flood larger than the planned scale occurs, the banks may break and cause flooding. In such a case, doing nothing simply because the flood is larger than planned is not an option; at the very least, the residents must be evacuated in order to save their lives.

As stated above, flood forecasting is required even for those areas where sufficient flood control measures are implemented, as well as for areas where flood control measures are still insufficient. Flood forecasting is attracting much attention as an alternative to flood control in areas with poor flood control measures, as is often the case in the Southeast Asian developing countries where there is inadequate investment for flood control due to financial constraints.

Since the Typhoon Committee was established under a joint project by ESCAP and WMO in 1968, it has provided a “Training Course for Flood Forecasting and Warning Technology” for engineers in those areas and has, as part of technical cooperation projects, dispatched research teams and supplied necessary equipment for establishing facilities for flood forecasting and warning by selecting model rivers in each country plagued with frequent cyclones. Examples include flood forecasting/warning systems for the Pangpanga River in the Philippines, Tansui River in Taiwan and the Hangang River in South Korea.

b. Legal Framework of Flood Forecasting

The basic law on flood forecasting in Japan is the Flood Fighting Law. The Law provides that the Director-General of the Japan Meteorological Agency (JMA) shall, if he so considers in view of meteorological conditions, advise the Minister of the MLIT and relevant prefectural governors that a threat of flood and/or high tide exists. The Director-General shall also make the public aware of such threats in cooperation with the mass media such as broadcasting stations, newspapers, news services and other media, if necessary. The Law also provides that the Minister of the MLIT shall, in conjunction with the Director-General of JMA, advise the relevant prefectural governors of the flood situation by indicating the water level and discharge for rivers flowing through two or more prefectures or rivers with a large catchment area that pose a threat of grave damage to the national economy in case of a flood, if a flood is considered likely. The Minister is also required to make the public aware of such threats in cooperation with the mass media, if necessary.

The Law also provides for flood fighting warnings, which is defined as an announcement for warning that flood fighting measures must be taken due to the threat of natural disaster by flooding or high tide. Namely, Section 10(4) of the Law provides that the Minister of the MLIT shall issue a warning for flood fighting on rivers, lakes and coasts that are designated by him as possibly causing grave damage to the national economy in the case of a flood or high tide, and prefectural governors shall issue a warning for flood fighting on rivers, lakes and coasts, except those designated by the Minister of the MLIT as possibly causing substantial damage in the case of a flood or high tide.

Table ?? below summarizes the matters defined by the provisions in the law.

Table ? Assignment of Flood Forecasting and Flood Fighting Warning

	Agency in Charge	Rivers to be Watched	Information Given	Who is to be Informed
Flood Forecasting	Minister of MLIT, Director-General of JMA	Rivers flowing through two or more prefectures or with large catchment area, which are designated by Minister of MLIT	Threatening state of floods with water level and flow rate	Prefectural Governors, Mass media by Minister of MLIT
	Director-General of JMA	Ordinary rivers	Threatening state of floods	Minister of MLIT, Prefectural Governors, Mass media
	JMA (Sec. 13, Meteorological Service Law)		Forecasting and Warning	Mass media
Flood Fighting Warning	Minister of MLIT	Rivers designated as possibly causing grave damage to the national economy by floods, etc.		Prefectural Governors
	Prefectural Governors	Other rivers		Relevant Flood Fighting Managers
	JMA (Sec.14(2), Meteorological Service Law)	Ordinary rivers	Meteorological mass media warning for flood fighting activities, Flood warning	MLIT, Prefectures, NTT

The Basic Law for Disaster Prevention promulgated in 1961 is a blanket law to cope with disasters, as its name indicates, to which the Flood Fighting Law is affiliated as one of the rules to implement the Basic Law. The state, local autonomous agencies and other public organizations are obligated to enact disaster prevention plans by the Law, and the Disaster Prevention Councils organized at each government level such as the central (State), prefectural and municipal governments must prepare the Basic Plan for Disaster Prevention, Prefectural Local Plan for Disaster Prevention and Municipal Local Plan for Disaster Prevention, respectively.

According to Section 35 of the Law, the Basic Plan for Disaster Prevention provides:

1. Comprehensive long-term plans on disaster prevention
2. Key points in the disaster prevention work plan and local disaster prevention plan
3. Other useful matters for preparing the disaster prevention work plan and local disaster prevention plan deemed necessary by the Central Disaster Prevention Council

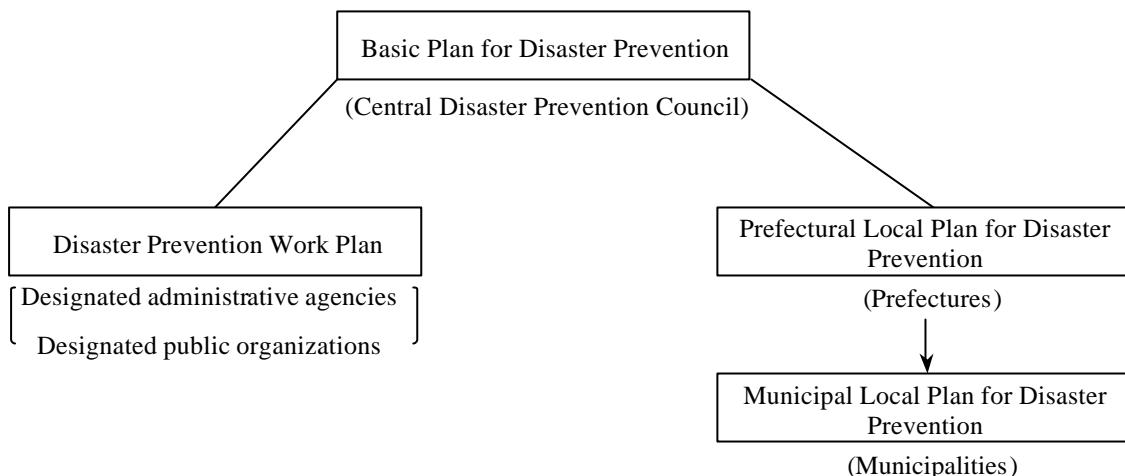
The disaster prevention work plan and local disaster prevention plan are prepared by the relevant parties under the Basic Plan for Disaster Prevention regarding matters, activities, and local areas falling under their respective jurisdictions.

Section 35 of the Law provides matters relating to flood forecasts and flood fighting warnings to be focused on in the disaster prevention work plan and local disaster prevention plan. Those plans must provide matters relating to:

1. Preparation of facilities relating to meteorological service
2. Preparation of facilities and equipment relating to flood fighting, fire fighting and rescue
3. Communication of forecasting and warning on disasters and how to issue a warning
4. Activities on flood fighting, fire fighting and rescue
5. Communication plan in the event of disaster

Usually, the people in charge of flood forecasting also draw up disaster prevention plans, but if not, then they must be well acquainted with the above disaster prevention plan.

Relationships of Various Plans for Disaster Prevention



Flood forecasting is important not only for the general public in preparing for and evacuating from floods but also for operators of such facilities as dams, and flood fighting warnings are important for flood fighting organizations to enable them to prepare and take position. It is therefore necessary to arrange in advance ways to communicate forecasts and warnings, and the communication routes through which they are to be transmitted.

As for rivers such as the Tone River and the Yodo River, for which flood forecasts must be issued jointly by the Minister of the MLIT and the Director-General of JMA, flood forecasting communication committees named according to the respective rivers are organized for implementing communication exercises from time to time and for keeping equipment ready.

To conduct this joint effort smoothly, the Director of the River Bureau of the MLIT and the Director-General of the JMA have concluded an agreement.

Whereas prefectural governors and municipal mayors are responsible for flood fighting that is closely connected with flood forecasting under the provisions of the Flood Fighting Law, the MLIT subsidizes the expenses for preparing flood fighting storehouses and flood fighting vehicles or for purchasing flood fighting materials. Currently, there are over 3,000 flood fighting management organizations in Japan.

c. Variety of Flood Forecasts and Flood Fighting Warnings

The Law does not specify what kinds of flood forecasts may be issued, but forecasting can be classified into two main categories, i.e. flood awareness advice for calling attention to the likelihood of a flood, and flood warnings to warn against damages by flood or the need to evacuate. Also, the flood information for providing details on floods is usually announced as part of the forecast. The standards for issuing those advices, warnings and information are defined in an arrangement concluded between meteorological offices and the Regional Development Bureau of the MLIT in charge of rivers for which the forecast is to be issued.

Variety of Flood Forecasting and Standards for Issuance

Variety	Standards for Issuance
Flood awareness advice	A flood is expected of a water level that may surpass the warning stage at any forecasting point.
Flood warning	The water level has surpassed the warning stage and is expected to reach or surpass the design high-water level in a flood or the possibility of a grave disaster exists.
Flood information	When it is required to supply supplementary information to flood awareness advice and/or flood warnings or to modify them, or when it is required to advise of the magnitude of a flood.

The table above shows what kinds of flood forecasts will be issued according to what standard for the Tone River and the Arakawa River.

A flood warning will be issued when the water levels of a river at designated staff-gages in a flood event are predicted to surpass the warning stage and are expected to reach the high-water level. In such a case, it would be unlikely for a bank to be broken if improvement work has been completed, but residents living along the river or low-lying lands should prepare for evacuation. If the water reaches a higher level and threatens bank collapse, a forecast to this effect will be issued and evacuation to an appropriate shelter will start simultaneously in accordance with the local disaster prevention plan. The chain of command in such a case is defined as follows (in the Basic Law for Disaster Prevention):

Prefectural Governor ? Municipal Mayor ? General Public

If the mayor cannot issue the evacuation instruction, a policeman or officer of the Japan Coast Guard may issue the instruction on his behalf. If faced with imminent danger due to inundation, the prefectural governor, an officer under his order, or a flood fighting administrator may issue the evacuation order.

It is essential to fully examine in normal time how and to whom information should be transmitted when a bank collapses, as experience shows that confusion often occurs in the chain of command; people wonder to whom they should send the relevant information, or it is sent to the wrong person.

Flood forecasts should be transmitted as quickly as possible. However, this is difficult unless substantial training is given in an ordinary warning system where two nodes of intermediate connections exist or the like. In one example of a communication exercise at a river site in Japan, it took a full hour for a flood awareness advice or flood warning to reach the end of the chain.

Next, the Law also does not provide for what kind of flood warnings should be issued; this is left to the decision of the individual flood forecasting organizations. Generally, warnings are given in five levels: readiness, preparation, turning-out, instruction and clearance stages, as shown below:

Variety of Flood Warning, Contents and Standards for Issuance

Variety	Contents	Standards for Issuance
Readiness	<ol style="list-style-type: none"> 1. To issue a warning to the flood fighting organization on the need to wait for turning-out for instantly responding to an emergency in case inundation or resurgence of rising water level is expected. 2. To issue a warning to the flood fighting organization that the number of personnel may be decreased, but flood fighting activities cannot be totally cancelled, if the turning-out period of the flood fighting organization is extended. 	When deemed especially necessary in view of the meteorological forecast, warning and river conditions
Preparation	To warn the flood fighting organization to be prepared for turning-out, and to communicate information on flood fighting, preparation of flood fighting material and equipment, inspection of and communication of other river conditions.	If deemed necessary due to precipitation, water level, and flow rate and operation of lock gates and ensuring communication of other river conditions
Turning-out	To warn the flood fighting organization of the need to turn out.	When the water level is likely to surpass the warning stage according to flood awareness advice or water level, flow rate or other river conditions
Instruction	To indicate clearly the water level, stage duration time and other conditions required in flood fighting activities, as well as to issue warnings by indicating overflow, leakage, slope collapse, cracks and other matters to be monitored according to river conditions.	When a disaster is likely to take place according to the flood warning, or when the water level has already surpassed the warning stage
Clearance	To advise that water conditions requiring flood fighting activities have disappeared and the series of flood fighting warnings issued in the name of the relevant reference water level observatory is cleared.	When the water level becomes lower than the warning stage or when it is deemed that the river conditions requiring flood fighting activities have disappeared, even if the water level is still higher than the warning stage

Readiness is a stage in which there is a likelihood of receiving an order for turning-out and in the preparation stage, various activities are conducted in expectation of turning-out. Flood fighting organizations are requested to take positions at flood fighting sites under the order of the flood fighting administrator. More detailed instructions are given to flood fighting organizations concerning especially vulnerable spots and necessary flood fighting works.

The Flood Fighting Law provides the following flood warning communication route:

Minister of the MLIT

?

Prefectural Governor ? flood fighting administrator ? flood fighting organizations

The actual communication route should be defined in detail by in-house assignment rules in each organization or based on the local disaster prevention plan as is the case of flood forecasting, but the time required for communicating to the end of the chain should be kept as short as possible. In the example of the Gonokawa River, which suffered severe damages in 1972, the expected time and actual time for each stage of data collection, analysis, preparation of warning statement and transmission of warning were as shown in the table below.

Expected Time vs. Actual Time (heavy rain in July 1972)

Type of warning	Activity	Required time (unit: minute)	
		Expected	Actual
Readiness	Data collection, preparation of warning statement	35 min.	15 min.
	Transmission to members of flood fighting organization	10	125
Preparation	Data collection, analysis, preparation of warning statement	65 min.	20 min.
	Transmission to members of flood fighting organization and gathering them together	10	45
Turning out	Data collection, preparation of warning statement	20 min.	15 min.
	Transmission to members of flood fighting organization, their arrival at the site	30	55

Note that the time required for preparing the warning statement was shorter than expected, but the time required for sending the warning and for the members of the flood fighting organization to turn out was much longer than expected.

d. Method of Flood Forecasting

Various hydrological methods of flood forecasting will be described in Chapter 3, but they are also outlined here to facilitate understanding of the general concept.

Currently, the following methods of flood forecasting are used in Japan:

- i) Estimation of downstream water level by precipitation of upstream points (e.g. Chikugo River)
- ii) Correlation between two points in upstream and downstream areas (e.g. Tone River)
- iii) Storage Function method (e.g. Yodo River)
- iv) Calculation of upstream flow using unit hydrograph for tracing with simplified basic equations and simultaneous equations for unsteady flow (e.g. Kitakami River)
- v) Tracing using strict basic equations and simultaneous equations
- vi) Coaxial relation chart (e.g. Chikugo River)

e. Facilities for Flood Forecasting

Facilities for flood forecasting require the following:

- i) Rain gage
- ii) Water level gage
- iii) Information transmission equipment
- iv) Data processing equipment

Precipitation data used to be sent by using a combination of an ordinary rain gage and a telephone call or telegram to a flood forecasting center, but nowadays almost all stations use a recording rain gage and telemeter. Water level gages are also equipped with telemeters whose recording paper need not be changed for a long period to facilitate maintenance.

The information transmission equipment consists of the aforementioned telemeters and communication lines for transmitting instructions and other data. Even though NTT lines cover most areas, in upstream mountainous areas, information is sent by the MLIT's microwave lines for flood fighting teams. The microwave lines for flood fighting connect with Tokyo and all prefectural head offices, and are also networked with private lines of the MLIT to form one of the most intricate information transmission networks alongside the communication lines of NTT and the police, and computers process the data.

2. History of Flood Forecasting

a. Beginning of Flood Forecasting

If flood forecasting is simply defined as stating the “likelihood of a flood” in advance, then its origins surely date back to ancient times. However, if it is defined as “presenting a situation by indicating the water level or discharge” as defined in the Flood Fighting Law, then the first flood forecast is thought to have been made by M. Belgrand in France when in 1876 he forecasted the flood level of the Seine three days in advance with an accuracy of within 1 cm.

On the other hand, little progress was made in Japan, but various studies had begun to be published in the 1920s and a system was developed for using flood forecasting in practice in the Hanggang River in the Korean peninsula in 1926.

In 1920 a large flood struck the southern part of Korea and the Hanggang River inundated too, causing huge damage in the areas around Seoul. Especially, the inundation of Ryuuzan station, which was a traffic hub, galvanized the public authorities who recognized the necessity of flood forecasting. As a result, officials from the railroad, police and civil engineering fields held meetings and decided to begin flood forecasting by informing, every 3 hours by telegraph, the water levels of two staff gages located at Ro-shuu on the Northern Hanggang River and Kahei on the Southern Hanggang River in the upper reaches of the Hanggang River. From these points, it would take some 12 hours for a flood to reach Seoul. The result was good and substantial benefits were obtained in ensuing floods in 1925.

In 1919 the “Rules for Reporting and Informing the Hanggang River Rising Water Level” were issued, followed in 1926 by the “Rules for Observation and Reporting of Precipitation for the Hanggang River Flood Forecasting”. This shows that flood forecasting had already become routine at the time, indicating the surprisingly advanced level. Meanwhile in Japan, studies on domestic rivers were successively published, such as the study on the Tone River by Kusuo Aoki, on the Chikugo River by Inokuma Ueno, on the Kitakami River by Kumajirou Namikawa, and on the Yodo River by Suketarou Sakamoto.

The methods used in those studies are either the so-called Water Level Correlation Method, which utilizes the correlation between upstream and downstream water levels, the so-called Precipitation Method, which analyzes the flow rate from catchment precipitation to convert it to water level, or a combination of them. Especially noteworthy are theses on the Hanggang River and two other rivers by Asajirou Kajiyama

that contain a similar concept as the Unit Hydrograph, which instantly attracted attention when L.K. Sherman introduced it in the Engineering News Record in 1932.

As stated above, even though many hydrological studies had been published, they were only used for actual flood forecasting much later after World War II, except the Hanggang River case. The reason was the limited awareness of the general public about the benefit of flood forecasting and the great difficulty of flood forecasting due to the undeveloped communication facilities in those days to cope with the rapid flow of flood water.

In 1936, the Tokyo Civil Engineering Office, the predecessor of the current Kanto Regional Development Bureau of the MLIT, informed the flood conditions of the Tone River to local work offices under its jurisdiction for use in flood fighting but details are not available. It is assumed that circumstances might have been the same in the other main rivers such as the Yodo River and the Chikugo River.

Following the experience of the great flood in the Tone River caused by Typhoon Catharine in 1947, orchestrated moves started to be taken: in the same year, the Kanto Regional Construction Bureau, the Forecasting Department of the Meteorological Agency and the Council for Resources Research of the Economic Planning Agency organized the Meteorological Communication Council which was the predecessor of the Flood Forecasting Communication Council after the Flood Fighting Law was enacted in 1949. The Meteorological Communication Council showed spectacular results when Typhoon Ion struck in 1948.

The enacted Flood Fighting Law provided that the Minister of Construction (now, MLIT) shall implement flood forecasting in 18 main rivers across the country to establish flood forecasting systems, but it was difficult to provide facilities for flood forecasting, especially facilities for communication. Under the US army occupation after World War II, authorization for use of radio waves for wireless communication was difficult to obtain. However, this issue was solved when in 1950 the Radio Law was enacted and in the same year 18 radio stations started operation along three river systems, the Tone, Kiso and Yodo Rivers. Later, the telemeter system was developed, which transmitted observation data automatically through wireless lines, bringing great progress to flood forecasting facilities.

b. Development of Runoff Calculation Method

In the latter half of the 1940s, a peak flow calculation study was conducted to apply Sherman's Unit Hydrograph to Japanese rivers, as well as a study of the flood routing method (Muskingum method), which is said to have been developed in the Ohio River, USA.

Regarding the Unit Hydrograph, many reports were published, such as a paper by Dr. Toujiro Ishiwara suggesting that its linear assumption does not apply to Japanese rivers, a study of methods for preparing the Unit Hydrograph by Dr. Nakayasu, which was widely used as the Nakayasu method, and Dr. Tachigami's study on the same subject.

Around that time Dr. Takeuchi, who studied under Professor Linsley of Stanford University, a global authority on world hydrology and one of the authors of Applied Hydrology, a classical textbook of hydrology, advocated, after he returned from the USA, the use of a calculation method based on the storage method.

Following this, Dr. Kimura suggested a calculation method based equally on the storage method that had been widely used under the name of the Storage Function Method.

During these periods attempts were made to represent flood flow as exponential functions, which were called runoff functions.

c. Introduction of Computers

According to the Applied Hydrology, attempts to conduct flood routing by machine were made by the U.S. Corps of Engineers in the 1940s, using a machine comprised of five drums and two motors. It was

designed to draw the water level and discharge volume of a reservoir on recording paper for a given inflow volume and dam gate operation data. Also, the U.S. Meteorological Agency made a so-called direct analog type flood routing machine that utilized the similarity of electric current and water current using the storage method as basic equations.

In Japan, a direct analog type flood routing machine was made available on the Yodo River in 1956. This simulator had a very fast calculation speed as it was an analog type and it was possible to complete calculations within 1/3600 of the actual time, enabling it to be used directly in flood forecasting. However, it was not possible to pursue the optimal operation of dams by using operations research methods, so another computer was required.

After the development of a flood simulator for the Kitakami River, river engineers focused on directly integrating basic equations of flood flow without simplification. This was actually put into use in the United States by J.J. Stocker in flood calculations for the Ohio River in 1954. He conducted his calculation on 400 miles along the Ohio River channel over a 6-day period by dividing the river channel into 5-mile sections and setting the calculation time t at 0.8 hour. His calculation using a UNIVAC computer is said to have taken 3 hours.

This report infused river engineers with a dream, a dream that came true with the large-scale domestic computer that was just emerging at that time.

In Japan, the FACOM 230-35 was introduced to the Yodo River Dams Integrated Management Office, which was established in 1969 following the Tone River Dams Integrated Management Office, to begin works including calculation for optimized operation of dams.

d. Development of Telecommunications

Today, work offices and branch offices of the MLIT are interconnected through private microwave telephone networks that enable them to enjoy rapid, secure communication during usual operation as well as emergency operation. Those lines are also connected with prefectural head offices to form important communication networks for emergencies such as flood and earthquakes.

As stated above, the Flood Fighting Law was enacted in 1949 to start organizing systems for implementing flood forecasting after Japan experienced consecutive large-scale floods in 1947 and 1948.

One of the difficulties of those involved at that time was the lack of means for quick and secure transmission of observed values of precipitation and water levels to the Civil Engineering Office (the predecessor of the Regional Development Bureau), which is the hub of flood forecasting. Those who were stationed at observation posts in those days must have suffered when they were forced to run in the rain and wind either to a post office to send a telegram or to a school or store that had a telephone, which was rare in those days. However, telephones could instantly become disconnected if a telephone pole fell during a cyclone, and the telegram is the same in this respect. The people in charge of issuing flood forecasts must surely have waited anxiously for data on precipitation and water level under the roar of a storm.

Upon the promulgation of the Radio Law in 1950, radio stations in the three river systems of the Tone, Kiso and Yodo Rivers were allowed to start operation only for limited purposes of flood forecasting and related emergency communication.

In 1951 radio stations were set up in other river systems and a mobile station (radio mounted on an automobile) appeared in the Tone River system.

The use of the current telemeter system for precipitation and water level started with the completion of the Maruyama Dam (1955) in the Kiso River system and the Ikari Dam (1956) in the Kinu River system.

In 1967 it was decided to establish new communication lines for flood and fire fighting jointly with the Ministry of Home Affairs and the Fire Defense Agency and by 1975 connections among all prefectural head offices had been completed, except Tokyo where it was not necessary to do so.

e. International Cooperation

Japan's economy has developed enormously due to the income-doubling policy in 1960, enabling Japan to actively extend economic and technological cooperation to developing countries. In the field of flood forecasting, training seminars on flood forecasting and warning systems started in 1969 by JICA following the establishment of the Typhoon Committee by ESCAP and WMO. This seminar was designed to train meteorological experts and hydrological experts of member countries of the Typhoon Committee and continuing until now as the river and dam engineering seminar, which aims to cover general studies of river engineering. In 1970, a pilot project was started in which research was conducted on flood forecasting and warning systems along the major rivers of member countries. Research teams of specialists were dispatched on several occasions, first to the Pangpangga River (Philippines) led by Mr. Hiroshi Inada, then to the Tansui River (China) and Hanggang River (South Korea). In those rivers, modern systems were completed as a result of such research.

3. Flood Forecasting Methods

a. Effect and Accuracy of Forecasting

Flood forecasting is subject to severe criticism since its accuracy will be judged by the subsequent occurrence of floods. Officials who are in charge of flood forecasting are therefore in a difficult position.

The primary objective of flood forecasting is to provide the general public as well as officials who are responsible for flood control with information on floods so that they can take all available measures to minimize the danger. If the forecasting of a definite flood turns out to be incorrect, the flood control efforts would be in vain. Conversely, if the forecasting that a flood is unlikely to occur turns out to be incorrect, severe criticism would be sure to follow. If an ambiguous forecast were made in an uncommitted manner, it would cause numerous problems among users who would not know how to interpret the forecast.

For the above reasons, flood forecasting must consist of all that is necessary to communicate commensurate with its objectives and accuracy.

(1) Requirements of flood forecasting :

(?) Flood forecasting must provide the **information necessary** to guide the users in making a decision on what actions to take in the case of a flood emergency.

(?) Flood forecasting must be **sufficiently accurate** for the users to decide on what actions to take.

Since these two requirements are correlated, they cannot be treated independently. However, if they are examined separately, while the former is more closely related to uncertainty of the information, the latter is more closely related to the actions that the users may take.

(2) Effect and accuracy of flood forecasting

To ensure that flood forecasting is effective, it must contain sufficient information with required accuracy. The factors related to the effect are as follows:

P: Correct forecasting ratio

G_o: Forecasting absolute gain: What is gained when actions are taken in compliance with the forecasting?

G: Forecasting relative gain: What is additionally gained when actions are taken based on the forecasting compared to when no actions are taken?

Q: Ratio of those who take actions in compliance with the forecasting

G_s: Society gain from the forecasting: What society gains from the forecasting.

L: Losses caused by flood

l : Losses caused by flood even if flood control actions are taken. Generally, $L > l$

E : Flood control expenses: Expenses necessary to take flood control actions. Generally, $L > E$

(3) *Assessment of Forecasting Accuracy*

Among the factors related to the accuracy of flood forecasting, the ones that are vitally important are as follows:

- i) Accuracy of runoff calculation
- ii) Accuracy of discharge obtained from rating curves

Although it is difficult to make runoff calculations that are compatible with what actually occurs, it is also a fact that there are no definite standards to determine the compatibility of runoff calculations.

The first edition of the ‘Guide to Hydrometeorological Approaches’ published by the WMO in 1965 provides one section that explains the approaches for determining the confidence level of hydrological forecasting figures. Based on the assumption that it is difficult to raise the accuracy of predicted value to a level higher than the original data, the book recommends employing the following formula to calculate the confidence level of forecasting figures on the grounds that it is desirable to employ a simple approach.

$$Y_{1,2} = Y\bar{c} \pm t(P)S_{Y-Y} \quad \text{---(A)}$$

or,

$$Y_{1,2} = Y\bar{c} \pm t(P)S \quad \text{---(B)}$$

Here,

$Y\bar{c}$: An expected value of forecasting values

S : Standard errors for the forecasting method employed

$S_{y\bar{c}y}$: Standard errors for individual forecasting values

$t(P)$: Deviation value for the given probability distribution

b. *Accuracy of Forecasting Methods*

(1) *Accuracy of Runoff Calculation*

Although there is little data available on the accuracy of runoff calculation, which constitutes the core of flood forecasting, the analytical results obtained from field surveys of floods that actually occurred at 234 points along 16 rivers in Japan can be employed as a reference.

Table: S^2 Values Obtained from Formula (C) Sample: 16 rivers

Methods	S^2
Unit Hydrograph Method	0.02466
Storage Function Method	0.01941
Kinematic Wave Method	0.02863
Method Unknown	0.03916
Average	0.02379

By comparing the observed flood discharge (discharge obtained from a rating curve) $Q_o(t)$ with the calculated value $Q_e(t)$, the compatibility level was examined by employing Formula (C). Here, Q_p designates the peak flood flow, while T shows the time or number of figures compared.

$$S^2 = \frac{1}{T} \sum_{t=1}^T \left(\frac{Q_o(t) - Q_e(t)}{Q_p} \right)^2 \quad \text{-----(C)}$$

Although the methods used in forecasting include Unit Hydrograph, Storage Function and Kinematic Wave, the values of S^2 were more or less within the range of 2.3×10^{-2} showing no distinct differences between the methods employed.

(2) Accuracy of Discharge Obtained from Rating Curves

Generally, the rating curves representing the relation between water levels and discharges are described by a secondary degree curve by employing either of the following:

$$Q = a(H+b)^2 \quad \text{-----(D)}$$

or

$$Q = aH^2 + bH + c \quad \text{-----(E)}$$

Here,

Q : Flow (m^3/s)

H : Water-level pole readings (m)

a, b, c : Constant

The errors that may be found in determining the discharge from rating curves can be classified into the following three categories: (a) errors that may lie in the observed values themselves, which are used as the basis for the preparation of rating curves; (b) errors attributable to the application of curves including the application of a single curve regardless of the time when the water level rises or falls; and (c) errors that may occur in the process of converting water level into discharge by using the rating curve obtained from discharge data on other floods.

As for category (a) errors, nothing definite is known. Since a float is normally used for discharge observation, the error is predicted to range from 10-20%, substantially greater in comparison with the observed values by a current meter at a low water level.

Category (b) errors seem to be relatively easily solved by the error theory. However, there are few instances in which this specific category of errors has actually been analyzed.

According to the study on the discharge at the Hirakata station of the Yodo River, the S^2 of the discharge as shown in Formula (C) was found to be of an order of 10^{-4} . Accordingly, regarding the error of discharge obtained from a rating curve, in combination with the error in the forecasting of discharge, disregarding this kind of error will not cause any problems.

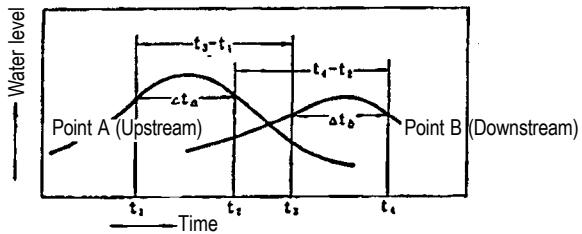
Category (c) errors can never be disregarded in the case of a river that exhibits significant riverbed movement. It is necessary to correct and renew the rating curves by conducting a cross-sectional survey without fail every time flooding occurs.

c. Flood Forecasting by Water Level Correlation between Upstream and Downstream

An approach to determining the correlation of water levels between two points at the upstream and downstream of a river is described as follows:

As shown in the figure, two hydrographs that correspond to the two points A (upstream) and B (downstream) are drawn respectively on a sheet of paper. Here, on the assumption that the water level (h_a) at

point A at the given time (t_1) corresponds to the water level (h_b) at point B, the time lag between the two points will be t_3-t_1 .



Comparison of Hydrographs

By the same token, the water level at point B that corresponds to the water level (h_a) at point A at the time the water level goes down must be h_b , assuming that the correlation of water levels between the two points can be represented by a single curve, regardless of the water level rising or falling. Hence, the time lag will be t_4-t_2 when the time that generates these water levels is set as t_2 and t_4 , respectively. The following formula can be obtained when this time lag is considered to be equal to the time lag at the time when the water level rises.

$$t_3-t_1 = t_4-t_2$$

As clearly shown in the figure, the following formula can be obtained by eliminating the common length of time, t_3-t_2 , in the above formula.

$$t_2-t_1 = t_4-t_3$$

In other words, water level h_b at downstream point B corresponding to water level h_a at upstream point A can be obtained by searching for water level h_b at the downstream point that can be held between the water-level and time curve at the downstream point in the length of time equal to time t_2-t_1 taken for the upstream water level to go down again and back to the original level h_a . Here, the time lag is given by t_3-t_1 .

Another approach uses the technique of plotting the water levels at two points observed at the same time when the water level rises and falls, respectively, as shown in the figure below.

The figure shows that the upstream level at 13:00 was 6.8 m, which reappeared at 13:00 on the same assumption as before, that the time lag is equal whether the water level rises or falls, downstream water level must be equal to the mentioned upstream water level of 6.8 m after 7.5 hours. This is equal to the time that has passed from when the 6.8-m water level was recorded upstream to the time observed at the water level curve that rose, as well as the time observed at the water level curve that fell. In short, the discovery of a level such as the one discussed above would correspond to the water level at the downstream

Although this method is somewhat complicated as it entails trial and error, it is determined to correspond to water levels that the inflow from a residual basin is Furthermore, it has the advantage that water level correlation drawings can be produced on the spot.

In addition, an approach to predicting water levels downstream from the water levels observed at multiple upstream points has been developed.

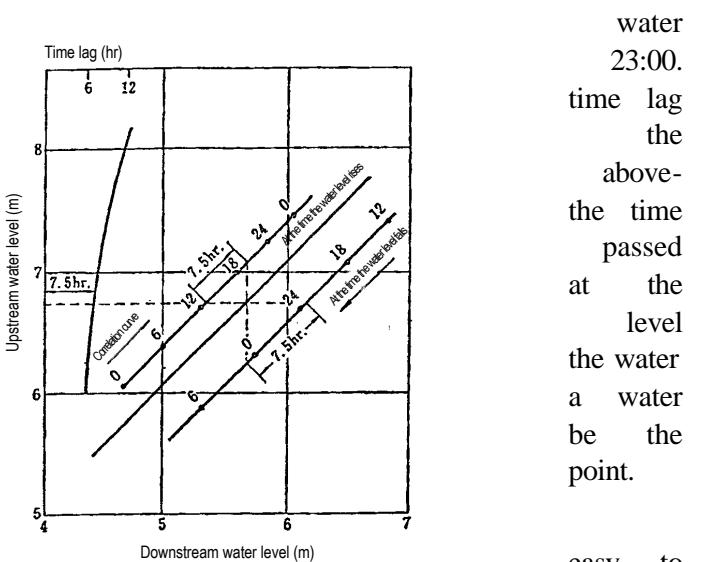


Fig. 2 Water Level Correlation Curves

easy to provided secured.

d. Estimation of Average Precipitation of the Catchment Area

One method employed as a major tool for flood forecasting is to predict flood discharge from rainfall, except for specifically large rivers. As a preliminary step, this section discusses methods for estimating the average rainfall of a catchment area.

Prior to flood forecasting announcements, forecasters must acquire rainfall information, which is included in the weather forecast issued by meteorological observatories. Unfortunately, meteorology has not yet reached a level that makes it possible to precisely predict river basin rainfall several hours or more in advance.

Alternatively, an attempt is made to collect information on the rainfall and water levels observed upstream within the basin at the earliest possible time and to predict flood discharge downstream on the basis of the collected information and data.

Rainfall is generally measured by the volume of rain collected in a receptacle 20 cm in diameter. This means that the gage can only determine precipitation on a point basis, not covering the basin as a whole. It is necessary to determine the volume of rain that has fallen over the entire basin before calculating runoff from the basin.

Although various methods are available for estimating the average basin precipitation from the rainfall observed at various points within and outside the basin, the following three methods are well known:

- (1) Arithmetical Mean Method
- (2) Thiessen Method
- (3) Isohyetal Method

e. Flood Forecasting by Storage Function Method

The storage-type runoff model has a long history. The Horton Method (1937), the Muskingum Method (1938) that hypothesized storage constants, and the Clark Study (1945) that discussed the relationship with the Unit Hydrograph, are just a few of the typical approaches. Toshiaki Kimura presented the Storage Function Method in 1961, following on the heels of the introduction of the above approaches. This method has been widely introduced and put into practice, especially by the MLIT. It is easy to obtain various constants from known rainfall and discharge data and the calculation formulae are relatively easy to understand in contrast to flood runoff phenomena.

Putting aside the details of the Storage Function Method, which are readily available in Kimura's papers and other publications, the elements applied to flood forecasting are discussed next.

The process of 'basin storage' is introduced into the rainfall-discharge conversion process in order to confirm the nonlinear characteristics of the runoff process in this method, which is the same approach employed by other storage-type methods. The results obtained from the above will be used as a parameter to obtain a functional equation that defines the relationship between the volume of storage and runoff and, further, to obtain a hydrograph from the calculation of the water incomings and outgoings of the stored volume.

f. Flood Routing by Muskingum Method

The Muskingum Method has been employed for many years as one of the flood routing methods. It was developed as part of the Muskingum Conservancy District Flood Control Project conducted by the US Corps of Engineers under the leadership of C.T. McCarthy in 1934-35.

g. Runoff Calculation by the Unit Hydrograph Method

The Unit Hydrograph Method was developed by Sherman in 1932 as an approach to calculate runoff from rainfall. This approach is also commonly used in Japan. Improved versions, called the Nakayasu Method and the Tategami Method, were developed in 1951 and 1955, respectively.

A general summary of the techniques used for calculating flood discharge is discussed here. Additional details can be found in hydrological books and related literature.

The Unit Hydrograph Method is based on the following basic hypothesis under the assumption that the rainfall-runoff process is linear.

- The runoff at the end of a basin caused by a unit effective rainfall will always yield the same flood wave, regardless of rainfall intensity.
- The runoff caused by the rainfall during the unit time is proportional to the intensity of the rainfall.
- The runoff caused by continual rainfall is equal to the arithmetically aggregated runoff generated by the rainfall during the unit time.

h. Estimation of Effective Rainfall

Unless the estimation of effective rainfall is correct as an input in calculation, the runoff calculation would result in laborious but fruitless work, no matter how strictly the tracing approaches may have been supplemented.

The actual mechanism of loss of precipitation (permeation) at the time of flood still remains to be fully explored in spite of the studies conducted by many researchers. It has been confirmed that the volume of permeation is larger in the initial stage of flood and decreases as time passes. The methods used to deduct the loss from the precipitation at various points in time are classified as follows:

- (1) Deducting precipitation loss at the initial stage of a flood (Tategami's Unit Hydrograph)
- (2) Deducting precipitation loss at a given ratio
- (3) Deducting precipitation loss at a given volume
- (4) Deducting precipitation loss by loss volume curves (Nakayasu's Unit Hydrograph)
- (5) Deducting precipitation loss by permeation capacity curves
- (6) Combination of the above-mentioned approaches (Storage Function)
- (7) Deducting precipitation loss in proportion to the basin storage volume (Tank Model)

Method (1) above assumes that the total rainfall is lost in the initial stage until the cumulative volume of rainfall reaches the loss volume and thereafter regards it as no loss. The Tategami Method attempts to determine the loss volume by correlation with the initial flow. The loss deduction at a given ratio as well as the loss deduction at a given volume treats the loss volume as a given ratio or volume in the initial stage of flood as well as in the later stages. Both the loss volume curve and the permeation capacity curve demonstrate that the ratio of loss will gradually decrease as time passes. The Nakayasu Method established a formula by means of a cumulative precipitation loss curve when it analyzed the precipitation loss in the study of the Chiyo River. A runoff analysis for flood forecasting in the Kitakami River is a typical example of using a Horton-type permeation capacity curve in calculating effective rainfall.

The above-mentioned approaches are employed in various combination patterns. For example, the precipitation loss deduction method combined with the Storage Function Method represents a typical combination of the above-mentioned approaches (1) and (2) separating a basin into permeable and non-permeable basins.

The loss deduction in proportion to the basin storage volume is capable of exhibiting the potential precipitation loss phenomenon seen in the midst of flood discharge that may occur even after the termination of rainfall. This method is applied in the Tank Model.

The precipitation loss or permeation at an occurrence of flood will be affected not only by the time-lapse change in the volume of rainfall but also by the geological conditions of the basin. For this reason, it is necessary to fully study and understand the actual conditions of the precipitation loss along the river basin by examining the correlation between the precipitation and the runoff based on as many floods as possible before determining the loss volume and the loss deduction method to employ.

4. Design of a Flood Forecasting/Warning System

a. Flood Forecasting System

A flood forecasting system should be defined as a collection of equipment and human resources put together for the purpose of issuing a flood forecast.

In general, a system will normally start operating with narrowly defined objectives, followed by expansion of operation to cover widened objectives, where lower-ranking objectives serve as means for achieving higher-ranking ones. For example, the action of “issuing a flood forecast” as the mandated objective can be understood as one of the means for achieving the superior objective of “protecting the life and property of the people”, and the action of “collecting data through a telemeter” is in turn one of the means for issuing a flood forecast.

A system also performs, according to its ranking, as a subsystem opposite a superior system, while acting as a controller of subordinate systems. The constituents of a system are the installations, operating staff and operation procedures. The installations comprise a visible physical presence including equipment and devices for detecting and converting information such as rain gages, equipment for transmission of information such as telecommunication devices, and equipment and tools for processing of information such as calculators and calculation charts, computers, etc., often collectively called “hardware”.

The operating staff means human resources and, when used here in connection with the subject purpose, is called the staff. The staff includes those who operate the equipment to achieve the objectives of the system, maintenance workers who secure smooth operation of equipment and devices, a supervisor who oversees the entire system including operation of facilities and assistant staff.

A system is often considered as a collection of machines and equipment, but the staff is an indispensable element of a system. No operators will be seen where unmanned machine operation is employed and the operation is running normally, but smooth mechanical operations depend on the support and maintenance services provided by the staff.

The operation procedures, often called software, may be memorized by the operators or recorded in writing, and provides the interface between the equipment and devices and between the equipment and devices and the staff. Unmanned operation means that the entire operation of a section of the process is stored in the memory of the relevant section of operation. The operation instructions may be retained in the memory of the operators but should be recorded in writing as well to avoid the loss of valuable information.

Whereas the above are the elements that are essential for a system to perform its objectives, there must be a subsystem standing by that verifies the smooth operation of the entire system, provides maintenance and inspection of the system, early discovery and repair of erratic operation and training of the staff to secure normal operation of the system.

b. Design of a Flood Forecasting System

(1) Setting the System Objectives

In designing a system, clear recognition of the system objective is the first and most important issue. The objective should be expressed clearly and quantitatively to the greatest extent possible. The items to be taken into consideration in designing a flood forecasting system are summarized below.

- (1) What kind of action does a flood forecast require for what decision making? (Examples): To operate flood control facilities such as dams, weirs, pump stations; To mobilize the flood fighting team; To issue evacuation orders, etc.
- (2) What kind of information should be provided? (Examples): The maximum water level; Time of the flood peak; Duration of time exceeding a certain level of discharge, etc.
- (3) What level of accuracy is required?
- (4) What is the minimum lead time for decision making?
- (5) What is the cost limit (in terms of the budget, staff, etc.)?
- (6) Others

Clear understanding of the points stated above is of prime importance for efficient progress of the system designing.

Regarding the development of flood control installations for evacuation of residents and/or facilities, consideration should be given to the fact that in some developing countries where neither flood control facilities nor levees exist, there are no options available other than to take refuge. In Japan, and especially in large urban regions, high water beds are often used for various purposes with many installations built, and warning of submergence of the high water beds is required.

For the objective of taking refuge at the time of disaster, information must be input into the system, such as the lead time required for taking refuge, the anticipated maximum water level and the length of duration at which evacuation is recommended. A sufficiently high accuracy is needed for the forecast of the maximum water level. In particular, the forecast of the threshold phenomenon of whether or not the water could overflow into low-lying flood plains must be as accurate as possible. The accuracy of the forecast of the duration of the water level could be less than in the cases discussed above. The time limit for issuing a flood forecast should be established by estimating the lead time required for evacuation preparation

Here, we discuss a flood warning system. With regard to major rivers in Japan, the main portions of the rivers are guarded by embankment, but if a river starts flooding to a certain extent, flood fighting actions must be taken, or the embankment itself will incur the risk of collapse. The scale of flood is generally expressed by the level shown on the water level gage for that portion of the river channel, with two predetermined levels, namely the “designated level” and the “danger level”.

Accordingly, the initial stage focuses on whether the forecast issued warns of the danger level at which the flood-fighting team shall be called in. A forecast of the maximum water level is also required, and if the forecast should turn out to be above the level of the embankment, subsequent actions would be the same as those in the case of the ‘danger level’ warning. The lead time for issuing a warning shall be determined based on the time required for the flood-fighting team to be prepared and called in for action. When the flood forecast is meant to trigger the operation of gates, etc., the required actions would be the same as in the case of flood fighting.

When a flood forecast is used for the operation of reservoirs, the forecast information should be given in the form of a hydrograph. In operating a dam, if the forecast accuracy of discharge by time is improved, the efficiency of the use of stored water would also be improved.

Next, we discuss the issue of budget and restrictions on staffing. These factors are highly dependent on the size of the benefit that weather forecasting provides. In particular, the size of staff directly reflects the

size of the parent organization. In this respect, the system design would be adjusted to achieve the optimum performance with the given size of staff. Ideally, 24 hours of observation and forecasting setup in shifts is required, but not quite possible in reality. Further improvements can be made to reduce human resources by employing unmanned operation and digitalization of information processing, to allow allocation of manpower only to functions where human judgment is crucial.

(2) *Features of Floods as Seen from the Perspective of the Flood Forecasting System*

In designing a flood forecasting system, it is necessary to recognize the features of floods in detail. Following are typical features of floods in steep mountain rivers in Japan:

Duration of a phenomenon is measured by unit of day:

A flood of a major river on a continent could last for several months. Assuming a speed of movement of 10 km per hour (3 m/sec.), a flood would take 100 days to flow down an expanse of 1,000 km, meaning three months or longer. This can be described as a slow-moving phenomenon against the vast expanse of a continent in the background, where the situation several hundred kilometers upstream can be conveyed to downstream societies long before the arrival of the flood, not necessarily through individual communication but through public media, allowing ample time for preparations and counteractions. Obviously, the number of technical difficulties is much less compared to that in Japan.

Flooding in Japan happens as a result of torrential rainfall caused by a seasonal rain front or a cyclone. In addition, a sequence of activities related to floods would take place within three days, starting with the initial forecast of rainfall as indicated by leading meteorological indicators such as a rain front or an approaching low pressure area, until the time the flood passes the area covered by the forecast. Accordingly, the flood forecasting system requires sufficient human resources that can be assigned to duty around the clock in shifts for three consecutive days.

The minimum unit of duration of the phenomenon could be a fraction of one hour

The minimum unit of duration of a flood phenomenon differs according to the size of the river in question. The rivers covered by a typical flood forecasting system are the large ones in Japan, where the water level can be measured hourly to present a frequently updated status. However, for the smaller rivers, it would be appropriate to employ 15 minutes as the minimum unit for any action. The unit of time for collecting and processing data should also be adjusted to match such a unit system.

The frequency of occurrence is low

If we look at any particular river over a long enough time, we can see that there has been or will be a flood without exception, at a frequency much higher than that of a fire breaking out. However, a flood does not happen every year, nor is it possible to forecast at the beginning of a year if or when it could happen. The flood forecasting system should, therefore, remain on standby at least during the flood season, and its entire system should be in working order during other seasons as well. Equipment should be maintained and the staff retained.

Flooding is an abnormal situation

The strong winds of a cyclone and the torrential rain that may directly cause a flood might also damage the observation and data communication network. Therefore, it is necessary to have a duplicate data communication system as a backup.

c. *Reliability of the System*

The flood forecasting system is complex, comprising various equipment and devices, installations, software and staff. A system with a complex structure cannot be completely free from mechanical or other troubles and errors. These problems, collectively criticized as weak in reliability, and their causes could originate from any one factor or a combination of any number of malfunctioning constituent parts of a PC,

failure in the system design or software, poor maintenance work, etc. A number of attempts to cope with this situation were made during World War II, and were completed in 1957 as Reliability Engineering. Ever since, the theory has been improved upon, and is widely known for helping to launch a number of space rockets comprising more than 10^6 parts and components. Granted, the flood forecasting system is a tiny system compared to space rockets or supercomputers, but the concept of Reliability Engineering is quite helpful in enhancing a system. A detailed description of Reliability Engineering can be found in technical documents, but the gist of the concept is introduced in the following section.

(1) *Reliability of Equipment*

Before discussing the reliability of a system, we should first check the reliability of the mechanical components that constitute the system. Reliability of the components will determine the reliability of the system as a whole.

(2) *Reliability of a System*

Defining degree of reliability is the quantification of reliability. According to the Japan Industrial Standard (JIS), “degree of reliability” is the probability of a system, equipment, or component performing the designated functions during the intended period of time, under predetermined conditions.

(3) *Redundant Systems*

A duplicate line of a system is not necessarily required from a technical point of view, but is very useful in terms of reliability of a system. A system having a duplicate line of equipment with the same functions for duplicate operations for the purpose of enhancing reliability is called a redundant system. Acquiring an emergency power generator for use when commercial power supply fails is a typical example of having a redundant system.

(4) *Fail-Safe System*

A system where minor trouble or errors, within certain limits, would not disturb the normal operation is called a fail-safe system. An everyday example is a camera with a shutter mechanism that will not work unless the film is fully wound. The flood forecasting system employs as its constituents computers and other precision equipment and devices that cannot be repaired in a short time. It should be supplemented by means of a fail-safe concept from a security point of view.

(5) *System Comprising Repairable Components*

A system comprising components that can be repaired is called a system accompanied by maintenance. Regarding the maintenance operation, the important questions are (i) Is the system design compatible with required maintenance work? (ii) Is there sufficient maintenance staff available? and (iii) Are appropriate working machines and tools available together with spare parts and supplies?

Maintenance is divided broadly into two approaches: maintenance services that are provided following a malfunction (ex post facto maintenance) and maintenance that is provided before any trouble occurs (preventive maintenance). All of the components that constitute the flood forecasting system should be repairable components. In view of the pattern of use of the system, which would be concentrated in only several months of the year but all functions should be fully operative without fail, and in consideration of the availability of maintenance and repair specialists and repair machines, space and other utilities, it is obvious that we should provide “preventive maintenance” for a flood forecasting system.

d. *Choice of Flood Forecasting Method*

Before starting to design a system for flood forecasting, the type of forecasting model must be chosen. For the majority of rivers in Japan, we employ a method for forecasting the discharge on the basis of the precipitation observed upstream of the river, and/or a method based on the water level of the upstream sections. The method based on precipitation is employed for all of the rivers for upstream areas, where in

actuality factors such as correlation coefficients between precipitation and water level, Unit Hydrograph, Storage Function, etc. are used, the results of which are in turn converted into the water level downstream using the correlation between the upstream and downstream water levels. For some rivers, including the Kiso River, Tenryu River, and Agano River, the correlation coefficients between precipitation and discharge, correlation between discharges at various points, correlation between discharge and water level, etc. are used because these rivers have a number of reservoirs and tributaries in their basin.

Prime factors for selection of a forecasting method include:

- (1) Size of the river: Area of the basin, length of the river and number of tributaries, etc.
- (2) Existence of reservoirs
- (3) Lead time allowed for issuing a forecast

The lead time is required for evacuation, flood control, data processing, forecasting work and transmission of the context of the forecast, respectively. Consideration of the existence of reservoirs is necessary in that a forecast of flood into reservoirs is sometimes required for control purposes and for security of dams.

The second determinant for a forecasting method is the accuracy required. There is not enough data available on the accuracy of various methods for flood forecasting, but in terms of spillover of river water due to heavy rainfall, a forecast based on coaxial correlation involving several other factors for calculation of discharge turned out to be more accurate than one produced on the basis of a simpler correlation. Furthermore, a forecast based on the runoff calculation using the Unit Hydrograph or Storage Function, etc. is superior in accuracy to the two above.

Regarding the change of flood wave forms in the downstream area, however, it is not always correct to say that flood routing by means of integration of the basic equation or tracking by the storage model is better than the method based on correlation of water levels or other simple methods. Therefore, the selection of flood forecasting methods from the perspective of accuracy refers to the methods for forecasting flood by rainfall.

The third factor that can also influence the choice of flood forecasting methods is the resources allocated to the given mission. This is a particularly important issue. The practical approach would be to first review the resources presently available for the purpose and, while conducting the forecasting operation on a temporarily structured system without making a rush decision, ensure that the system is being improved over time to achieve the optimum architecture.

It should now be clear that flexibility in responding to the required length of lead time is the most important factor in choosing a flood forecasting method. Items concerning flexibility in lead time are briefly described below.

(1) Time Required for Evacuation, Mobilization, etc.

There is no clear provision in the Flood Prevention Law on how far in advance a flood forecast or warning should be issued before the anticipated phenomenon. However, for the forecast to be worthwhile, it must be issued early enough to allow lead time as shown in the table below. An appropriate advance notice means a notice to make recipients aware of the threat of a large flood and prepare for a possible evacuation order or, in the case of members of the flood fighting team, a mobilization order. If such an advance notice has been issued, people can prepare for the suggested actions and lead time could be saved. The 30 minutes allotted here allows residents in the endangered area to move without panic to a designated shelter such as the auditorium of a nearby school. If the shelter is far away, then the warning should be given with a longer lead time.

In the case of flood prevention warning, actual flood fighting actions are anticipated. The mobilization time here means the time required for the flood fighting team to get to the site with the necessary equipment and materials by the predetermined means of transportation.

Lead Time for Flood Forecasts and Flood Prevention Warnings

Type of announcement	Timely advance notice given	No advance notice given
Flood forecasting	30 minutes	1 hour
Flood fighting warning	10 minutes + Mobilization time	20 minutes + Mobilization time

* The time indicated above does not include the time required for transmitting the forecast/warning itself.

The flood forecast and warning are first conveyed to the administrative organizations, mass media, and finally to the flood fighting team and general public. Therefore, the time spent for communication with privileged parties, which is estimated to be about 30 minutes, should be added to the above. In an area with poor communication means or the like, extra time should be allowed in accordance with the local conditions.

(2) Time Required for Preparation of Forecasting

The time required for issuance of flood forecasting is summarized in the following table.

Table Summary of Lead Time Required by Flood Forecasts

No.	Item	Flood forecast (Min.)	Flood warning (Min.)
1	Data collection	30	30
2	Forecast calculation		
3	Consultation with related organizations	5	5
4	Drafting forecast statement	5	5
5	Transmission of forecast	30	30
6	Time allowed for evacuation/activities	30 - 60	30-60 + mobilization
Total time required		100-130 minutes	80-90 minutes + mobilization

(3) Selection of Forecasting Method

To select the appropriate method for a specific river basin, the following items should be taken into account.

Table Check List for Selection of Flood Forecasting Methods

	No.	Item	Remarks
Flood	1	Area forecast required	
	2	Time of flood concentration	
	3	Time the flood flows	
Evacuation	4	Flooded area	
	5	Place for refugees	
	6	Maximum time for evacuation	
Flood prevention	7	Point in danger (location in need of flood-fighting actions)	
	8	Base for flood-fighting team standing by	
	9	Maximum time required to mobilize flood-fighting team	
Communication	10	How the communication systems are working	
	11	Maximum time required for disseminating required information	
Forecasting time	12	Time required for collection of data and calculation for forecasting	
	13	Time required for consultation with relevant organizations and for drafting forecast statement	
	14	Time for conveying the forecast (6) + (11) + (12) + 10 min. or (9) + (11) + (12) + (13) + 10 min.	
Method for forecasting	15	Necessity of rain forecast (No if 2) > 14); Yes if 2) < 14)	
	16	Necessity of forecast of discharge from rainfall (No if at location 8) 2) > 14); Yes if 2) < 14)	

e. Deployment of Rainfall Gages

Meteorological and hydrological information is crucial for the flood forecasting system and should be transmitted to the office responsible for flood forecasting and warning without delay. Although various types of rain gages are used to observe precipitation, the tipping-bucket type of recording rain gage is used in flood forecasting systems, because it is more suitable for the telemeter system. Although a telemeter is desirable and even essential in some cases, it requires relatively high cost and intensive input for maintenance and operation. Therefore, when the necessary information must be securely collected, the telemeters employed should be limited to the minimum number.

In determining the deployment of rain gages, the first factors to consider are:

- (1) Permissible error in average rainfall in a basin;
- (2) Observation systems to achieve necessary accuracy;
- (3) Back-up systems;
- (4) Operation and maintenance of facilities;
- (5) Required budget.

f. Deployment of Water Level Gages

It is recommended that water level observation stations for flood forecasting be selected from existing stations to avoid duplication of investment and confusion over data and information. If there are no appropriate stations, additional observation stations will be established. In selecting stations or locations for additional stations, the following factors should be considered:

- (1) Areas to be covered by flood forecasting and warning
- (2) Locations around dams :
 - i. Immediately above a dam, and
 - ii Upstream of a reservoir or downstream of a dam.
- (3) Tolerance of facilities;
- (4) Locations immediately upstream, or when applicable, downstream of a junction of an important tributary; and
- (5) Other locations important in terms of flood forecasting or flood protection

g. Communication Systems

Communication systems must be reviewed separately in terms of their aptitude for collection of hydrological data and for transmission of flood forecasts, flood fighting warnings and warnings of release of water from reservoirs, etc.

Data collection and transmission of data at the time of flooding include :

- i) Flood forecasting body sends its staff to the site to read and bring back the measurements;
- ii) Observer appointed for the each observation station shall visit the site to read and report the measurements by telephone;
- iii) Observer shall read and report the measurements by mobile phone or portable wireless radio;
- iv) Collect data through telemeter system via public telephone facilities; and
- v) Collect data from telemeter system via proprietary circuits owned by river administrators.

It is desirable to have the main and emergency route in parallel to avoid failure of transmission of data and information. In the case of observing the precipitation in the mountains at the upstream of a river,

deployment of a telemeter system is desirable since it is the only way to obtain data from such a remote place. In the case of the Tone River Integrated Dam Control Office, when rainfall data has not been collected, rainfall at the station is estimated using correlation with nearby observation stations.

On the other hand, most of the water level observation stations are located near villages or towns, and it is easier to establish backup systems for observation and communication.

h. Transmission and Dissemination of Flood Forecasting

For transmission of a flood forecast under the provisions of Article 10 of the Flood Prevention Law and of flood forecasting under the provisions of Article 10-4 of the same law, the set-up on the part of the transmission recipients is expected to be organized as shown in the figure below. In reality, however, transmission of this information is performed among and between the working organizations to the extent allowed by each organization's rules for delegation of authority. For example, at the Ministry of Land, Infrastructure and Transport (MLIT) the authority to issue a flood forecast was vested primarily to the Director General of the Regional Development Bureau, which was then delegated further to the general manager of the competent work offices of the respective rivers assigned to their administration, except for major rivers such as the Tone River, Yodo River, Kiso River, etc. Issuance of flood warnings has always been entrusted to the general manager of each work office, while flood forecasting is entrusted to the general manager of the competent construction office designated for each river system. The network used for transmission is also determined in detail in accordance with the above, for the purpose of transmitting the information securely through the routes established to all parties in the communication network.

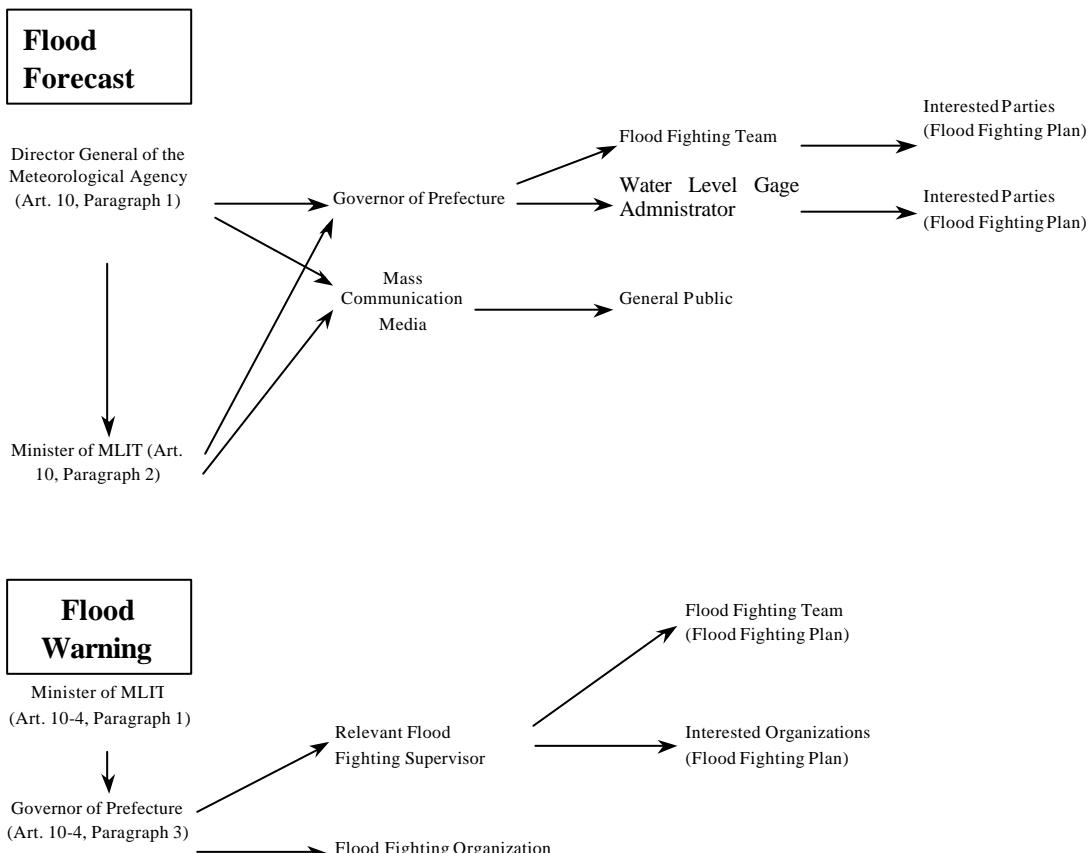


Fig. Transmission of Flood Forecast and Flood Fighting Warning

5 Recent Developments and Application to Other River Basins

a. Outline

The system comprising measurement / transmission / analysis / judgment / dissemination / action was established in Japan in the 1970s after extensive studies and considerable investment. Since then the

system operates as the principal flood forecasting/warning system in Japan. But the environment surrounding flood forecasting/warning is changing substantially. Specifically, the degree of precision and density of observations have both improved, as, in the meteorological field, weather forecasts have become more dependent on satellite information and at the same time as high-density surface meteorological observations are performed by AMeDAS (Automated Meteorological Data Acquisition System) that uses commercial telephone lines. Moreover, deployment of the rainfall radar network that stands between surface and satellite observation systems is expanding. In the hydrologic field, equipment that uses floats to measure water levels have almost all vanished and been replaced by other devices such as digital or water pressure type. The biggest changes during the last ten years have been the explosive development and spread of personal computers, and the progress in communication systems. From the era of postal mail and cable as the major communication media through the period dominated by telephone and fax, the era of optical fiber cable and the Internet arrived.

While progress in flood protection measures has lowered the frequency of breaching of dikes on the main streams of large rivers, concern has shifted to urban flooding accompanied by water-logging that disrupts urban functions and submerges subways and/or underground shopping malls, resulting in severe economic damage and the loss of many lives. Changes in the need for and content of flood forecasting and warning have become obvious.

The remarkable economic growth that has occurred throughout Asia since the 1970s has permitted investment in flood control projects, but the concentration of population and property in flood-prone areas has invited a rise in the potential for flood damage. This means that the significance of flood warnings has increased in a sense that is different from that in Japan.

In response to the above circumstances, this chapter clarifies the changes that have occurred in the past 20 years and the future challenges in the field of flood forecasting and warning. It also describes problems that could obstruct the wider application of these systems to rivers in Asian countries that not only feature differing natural environments, but slightly contrasting social and economic environments.

b. *Changes in Circumstances since the 1970s*

(1) *Meteorological and Hydrological Observations*

Electronic sensors replaced the mechanical sensors that had been used during the 1960s for meteorological and hydrological observations such as rainfall and water level, etc. For example, the float/pulley system that was the major type of water level gage used in the early 1960s was replaced by the electrical relay type digital water level gages by the 1970s, and these are now being replaced by precise water pressure type gages. Surface rainfall observations are still performed primarily by tipping-bucket rain gages, but the installations of rain radar systems that clarify rainfall phenomena over wide areas has continued and now cover the entire Japanese archipelago. The Tropical Rainfall Measuring Mission (TRMM) began in 1997 when NASA and NASDA jointly launched the TRMM satellite, permitting high-precision direct observations of rainfall from orbit.

Great progress has been achieved in the recording device of observation systems. The method used in the 1960s was the triangular pen/recording drum system, but this was replaced by the glass tube pen/recording drum system, multi-dot recorder, and cassette tape recorder, that were in turn replaced by memory tips. Thus recording media that is not only safer and more reliable, but can be incorporated into computer systems without modification replaced traditional recording devices.

The rain observation telemeter network was almost complete by the early 1970s, but since the completion of AMeDAS that began operating in 1974, rainfall observed at more than 1,300 locations is instantaneously archived through NTT circuits.

(2) *Communication Systems*

Since the 1970s, the most extensive changes have taken place in communication systems. The Ministry of Construction (now the Ministry of Land, Infrastructure and Transport) completed a microwave system exclusively for disaster mitigation activities in the 1970s, but the intervening years have brought a long series of advances including the privatization of the public telephone business, opening of telephone lines to data transmission, the development of satellite communications, spread of cellular phones, and the penetration of optical fiber cable. The Internet that had become the heart of data communication by the mid-1990s continued to increase its capacity and speed with the arrival of broadband in 2000.

Japan's flood forecasting and warning systems are still dependent on the microwave central computer system that was completed in the 1970s, presumably because those facilities are not yet amortized. When the present system must be reconstructed, it will likely be replaced by a completely different revolutionary system.

(3) *Data Processing Systems*

In the 1970s, data processing systems were constructed premised on large high-speed computers. The reason for this is that in Japan where there are many steep and short rivers, it is essential to process data as quickly as possible because of the extremely short lead time until the arrival of floodwaters, and at that time, computers were expensive and valuable. Later, the capabilities of personal computers rapidly improved and their use spread quickly, but systems installed in the 1970s are still operating and the only role given to personal computers has been that of information terminals. However, because of the change in the content of forecasts and warnings that must be provided, there is now a need for the provision of information that more closely reflects local conditions than in the past. When the present system must be reconstructed, the centrally controlled system now in use will be replaced by a system under decentralized control.

(4) *Changes in Flood Forecasting and Warning Needs and Contents*

The types of flood that must be predicted have changed as floods caused by overtopping and levee breaching were replaced by water logging and inundation type floods, which in turn, have given way to urban floods and sediment disasters. This process has altered the public role of flood forecasts and warnings. For example, while the most important factors that must be forecast in the case of overtopping and bank breaching are peak discharge and maximum water level, the most important index in the case of water logging, inundation floods, and urban floods is the total volume of inundation water, which corresponds to inundation duration and depth. Also, warnings must be issued based on accurate forecasts including the route that the inundating water will flow, the area it will inundate, and its effects on structures. It is also necessary to consider the difference of social structures between rural areas where the population density is relatively low and densely populated urban areas where organized response by people is difficult. Another change has been an increase in the importance of measures to prevent sediment disasters. This change has taken place because on one hand, i) disasters caused by sediment have more severe impact on human life and have attracted greater public attention than those caused by water-logging or inundation, ii) urbanization has increased the number of people living at locations at high risk of sediment disasters, and iii) flood control projects have reduced occurrence of ordinary flood damage, while on the other hand, the emphasis of disaster prevention measures has tended to shift to sediment disasters that now occur with increasing frequency. These are ways in which the need for and content of forecasts and warnings have changed.

(5) *Uses of Flood Forecasts and Warnings*

The revision to the Flood Fighting Act in 1955 ended the era when warnings of floods were based only on meteorological forecasting by adding the water level in rivers to the items to be forecasted. After that, flood warnings were provided to ordinary residents as meteorological information and modern hydrological flood forecasting was started as a way to carry out effective flood fighting activities. In Japan, hydrological flood forecasting has achieved great progress to reach its present level. The original motive for this progress was to assist flood fighting activities, but later it became to secure efficient operation of

reservoirs, weirs, and other flood control structures. As a result, use of hydrological flood forecasting in parallel with meteorological flood forecasting has continued to the present time in Japan. However, changes in the social and economic structure and in people's life styles have subsequently changed the requirements of forecasts and warnings. Simply stating that "a large flood may occur" has become inadequate to meet the needs of both industries and individual residents. This means that the results of hydrological forecasting that had only been used by experts up to that time came into wide use by both corporations and by individuals along with the increase in preparation of hazard maps.

b. Application to Rivers in Asia and Challenges to their Use

In Asia where the Asian monsoon causes heavy rains and forms humid zones, and where the action of plate tectonics creates mountains and volcanoes and forms alternating alluvial and diluvial plains in the downstream, the hydrological environment differs from that in other parts of the world. The population density and the level of economic activities are extremely high, and the potential for natural disasters is much greater than in other regions. Of these, flood inundation, water logging, sediment flow and other water-related disasters have obstructed regional, social and economic development. Under these circumstances, when ECAFE (now ESCAP) was established as a regional body of the United Nations, flood damage mitigation was included among the top challenges of the region and the Mekong Committee and the Typhoon Committee were established. The Typhoon Committee was established in 1968 with the support of ESCAP and the WMO. The first theme the committee took up was flood forecasting and warning, and later the activities of the Typhoon Committee were expanded to include TOPEX (Typhoon Operational Experiment) and flood risk mapping. However, because the achievements in more advanced countries such as Japan and Korea were introduced into the Typhoon Committee regions too quickly, their success has been limited. When applying systems and technologies, even in regions with identical natural conditions, they must be matched to the social and economic conditions in each region. In the implementation of the flood hazard mapping project in pilot areas that the Typhoon Committee commenced recently, this must be kept in mind, while the possibility of international cooperation is expanded as many countries in Asia have taken the first step in economic development.

(1) Differences in Natural Conditions

In Japan, the Storage Function Method that has few parameters is used by almost all flood forecasting systems because on a short and steep river in a mountainous region, the main component of flood discharge is the primary (surface) runoff. Furthermore, because flood concentration and arrival time is short in most of the Japanese rivers, the flood runoff model is used far more often than the water level correlation method. However, the water level correlation method is recommended for a large river because in such rivers it is possible to obtain adequate lead time. If the flood runoff model is used to forecast flood on a large river, the Tank Model Method that can account for the secondary runoff (mid-term) and tertiary (ground water) runoff is more appropriate than another storage type runoff model. In the 1970s, when the use of computers began to increase, a large-scale and complex model was created, assuming that a more detailed model would increase precision. But in a man-machine system such as a flood forecasting and warning system, the complexity of the model may increase difficulties in interpretation of predicted figures by the officers concerned. Therefore, simplifying the flood forecasting model is worthy of study.

While there have been many research projects on flood runoff models, there are serious problems such as delays in establishing field observation systems for rainfall, water level, and discharge, etc. that are the premises for the model. Establishment of telemetering and other information communication systems is also an urgent need in many countries. It is important to continue to expand, maintain, and operate observation and communication systems, and carry out other steady efforts to accomplish the final goal of the flood forecast and warning system.

(2) *Flood Forecasts and Warnings as Comprehensive Countermeasures*

The final goal of flood forecasting and warning is to minimize the flood damage by providing forecasts and warnings in order to 1) monitor, maintain/operate, and reinforce river facilities such as levees, weirs, etc.; 2) appropriately operate reservoirs, pump stations, and other flood control facilities; 3) have the national government, regional governments, and other administrative bodies implement necessary measures such as issuing evacuation orders; 4) provide appropriate advice necessary for flood fighting activities; 5) have companies operating railways, electric power, telephone, gas, and water supply systems, and other lifelines take necessary measures; and 6) give guidance to ordinary companies and individuals so they will act appropriately. To achieve the final goal of flood forecasts and warnings, it is necessary to 1) revive awareness of the purposes of flood forecasts and warnings; 2) select forecasting and warning systems suitable to these goals; and 3) to make preparations and take measures on the side receiving the forecasting and warnings. Each of these goals can not be achieved only by issuing appropriate forecasts and warnings at suitable times. It is essential to implement comprehensive measures including guaranteeing warning and forecast dissemination and transmission methods, establishment of flood fighting organizations and provision of flood fighting materials, carrying out information dissemination drills, evacuation drills, and flood fighting training, and education of people together with preparation of flood hazard maps.

(3) *Advantages for Rivers in Asia*

As stated before, the flood forecasting and warning system established in Japan in the 1970s is in a transitional stage. One reason for this is that it is a legacy of the 1970s typified by a microwave network. Inversely, it is not necessary for a developing country to discard its existing legacy and replace it with a new system. The foundations of the construction of a flood forecasting and warning system of a new generation are rainfall radar, rainfall observation satellites, and other stable and low-cost observation systems, satellite communications, cellular phones, broadband and other communication systems, broadcasting and information dissemination systems such as satellite and internet broadcasting, personal computers and a rich selection of software, etc. that permits the application of GIS and other new concepts. In this sense, the IFNet (International Flood Network) that was approved at the Third World Water Forum by many countries where neither flood control facilities nor levees exist, is counted on to make a future contribution to achieving its goals: sharing of information concerning floods and using rainfall observation satellites to monitor and announce warnings of floods. It is also counted on to complete the most advanced systems that meet the needs of developing countries in the field of flood forecasting and warning in the same way that cellular phones and satellite broadcasting have spread faster in these developing countries than in developed countries.