FOREST CONSERVATION AND REHABILITATION IN FLOOD HAZARD REDUCTION: EXPERIENCES FROM USA, CHINA AND MALAYSIA

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Abstract

Increasing incidence of floods in recent decades in many countries, particularly the USA, China and Malaysia have been largely attributed to loss of natural water retention systems such as forest ecosystems. Research has shown that natural undisturbed forest systems are the best forms of flood defence. Furthermore, rehabilitated forests, though not as effective as their natural counterparts, are also capable of reducing flood hazards. Forest systems, in contrast to urban systems, are stable and possess inherent mechanisms and their own ways and means of maintaining the hydrology of an area. In the USA, riverine forests and floodplains, also commonly known as wetlands, is nature's way of controlling floods but their replacement by urban and agricultural land use has resulted in increasing flood hazards. In China, loss of upstream forests and lakes/wetlands has also resulted in greater incidence of floods. Forests and wetlands also control floods by retaining rainfall at source, a concept only recently adopted by flood control agencies in Malaysia. Multi-structured densely forests intercept a significant amount of rainfall and can regulate the flow of rain outside the system. Important processes such as interception, throughfall, at-source storage, infiltration and vegetated surface impedence, reduces the flow and prolongs the rain from reaching the river. Least interception occurs when forests are thinned and exposed due to clearing, while maximum interception occurs with dense virgin forests made up of evergreen trees. Forests hold the water and release it slowly. When forests are cleared or destroyed, all the rain water gets into rivers at a relatively rapid time, resulting in flash floods. The concentration of water into the main river channel over a much shorter period of time dramatically increases flooding. It is vital for engineers and all scientists to work with natural systems rather than against them. In this respect, there is a shift towards using natural systems to manage floods in the USA and China. In Malaysia the mandatory Manual for Environmentally Friendly Drainage which focuses on at-source retention of rain for all development projects and forest conservation programmes are employed to reduce floods.

1.0 Introduction

The Asia-Pacific Region is a region affected by a wide range of natural disasters, ranging from earthquakes to volcanic eruptions, floods, storms, tsunamis, landslides, etc. Of all these disasters, none affect more people and bring about more damage than floods. Some of the major flood events in the Asia-Pacific Region are shown in Table 1. Parker (2000) noted that at the dawn of the 21st Century, the world was besieged by disasters, most notably floods. He further noted that the escalation in flood disasters world-wide were due to unsustainable development in the Asian "Tiger Economies" (including Malaysia), increased exposure to flooding due to floodplain encroachment in Europe, and widespread deforestation and land use change in the USA and China. Deforestation for human land use (mostly agriculture) reduced natural forests coverage in the Asia-Pacific region from about 510 million ha in 1980 to 480 million ha in 1995 (FAO, 1997). On the other hand, croplands have increased from 440 million ha in 1980 to more than 470 million ha in 1995. As a result, land degradation has resulted in environmental hazards of which flooding is one of the most serious (United Nations, 2000:6). More importantly, urbanization is changing the hydrological regime when natural areas are paved over by impervious materials, leading to more surface runoff and greater flooding. Cities are expanding and many encroaching into hazardous floodplains. The rate of urbanization in the Asia-Pacific has almost doubled between 1980 and 2000, reaching the current 37 % urbanization (United Nations, 2000:148). With the exception of a few developed countries, generally the rate of poverty in the Asia-Pacific is high, contributing to vulnerability of populations to disasters. Consequently, losses caused by natural disasters are particularly damaging, depriving countries of resources which could otherwise be used for economic and social development. Since1990, the total number of deaths due to natural disasters in the region is estimated at more than 200,000 and the estimated total property damage estimated at more than US$50 billion. Most of the deaths and damage are due to floods. For example, tens of thousands perished in the 1995 and 1998 floods in China. In the 1998 floods, 223 million people were affected, one-fifth of China's population while 3,004 people died and 15 million made homeless. Total damage in the 1998 China floods was estimated at US$12.5 billion, equivalent to 4.5 % of the country's GDP. In Bangladesh, the storm surge flooding in 1991 killed 140,000 people and affected the lives of 25 million people in the floods of 1998 (United Nations, 2000:205).

All three countries in this paper, viz. USA, China and Malaysia, have a long history of floods. In each country, flooding is due to a combination of either natural or human causes. The many reasons for flooding are exposure to monsoon winds, heavy convectional rainfall, frequent occurrence of storm events, low-lying topography, deforestation, floodplain encroachment, sedimentation and reduction of river capacities, changing climate, changing land use, and a variety of other causes (see Parker, 2000: Part VII:89-180). However, the flood hazard literature recognizes that flooding in theses countries in recent decades are mostly due to human causes – viz. rapid land use change that has impacted negatively on the hydrological regime. In the USA, the Mississippi basin has experienced massive flooding in recent decades as a result of loss of upstream forests and riverine vegetation (mostly wetland forests) (White, 2000; Changnon, 2000; Laska and Wetmore, 2000). In China, the Yangtze floods (especially the flood of 1998) epitomises the degree to which humans have decimated the environment, particularly with respect to wetlands destruction (Cai et al., 2001). In the 1998 flood, it was noted by the Chinese authorities that sharp declines in natural reservoirs such as forests and lakes, increased silting of rivers and lakes from the de-treed lands in the Yangtze basin, and steady encroachment on river beds by Chinese farmers have combined to push the flood waters to record levels during the 1998 Summer floods. Although the Yangtze River flow rates in 1998 were below historic highs, the flood levels were setting record highs because of silting due to forest and wetlands clearing. Satellite photographs taken over the past decade show increasing numbers of land-poor farmers encroaching into wetlands.

The literature clearly notes that forests ranging from highland montane forests to lowland rainforests and coastal cum riverine floodplains, commonly known as wetlands, are nature's way of controlling floods (Parker and Thompson, 2000:192; Chan, 2002a; Chan, 2002b; Chan, 2003). Forests and wetlands such as swamp forests control floods by intercepting rainfall at the canopy and regulating the flow of rain down branches, trunks and roots before reaching the river. Interception, the amount of rainfall caught in the forest crown, is about 10-15% of total rainfall. Least interception occurs when forests are thinned and exposed due to clearing, while maximum interception (often reaching 100 %) occurs with dense virgin forests made up of evergreen trees (Chan, 2001). During heavy rainstorms, rainwater commences to drift as mists or droplets to earth as "throughfall" which averages about 75 - 85% of rain in humid climates like Malaysia (Chan, 1991). Runoff from upstream also has to penetrate upland forests and downstream wetlands before reaching the river, hence increasing lead time (Chan, 2004). Riverine forests (acting as river reserves) and wetlands adjacent to rivers, estuaries and coastal areas also give runoff from precipitation (which eventually gets into rivers) a place to spread out, serving as natural retention basins (Nor Azazi Zakaria et al., 2004). Wetlands act like sponges soaking and absorbing a lot of water down into the ground and then releasing it slowly over time. Research has shown that as much as 2.3 million litres of water is absorbed per hectare, depending on the nature of the soil. Wetlands hold the water and release it slowly. However, when wetlands are cleared or destroyed, all the rain water gets into rivers at a relatively rapid time, resulting in flash floods. The concentration of water into the main river channel over a much shorter period of time dramatically increases flooding. Hence, increasingly, experts are recommending the use of rainfall retention at source methods to control floods (Aminuddin Ab Ghani, 2004).

Deforestation and rapid land use change due to accelerated economic growth have destroyed the natural forest cover replacing it with exposed or partly exposed surfaces. In Penang Hill, part of which is a water catchment area, many forested areas have been cleared for orchards and illegal squatter housing. Other activities that have had a similar effect on the land use are mining operations, construction of housing, logging and clearing of forests, highway construction, agriculture estates, quarrying and urbanisation (Chan, 1999). All these have caused high concentrations of suspended sediment in downstream stretches of rivers. Typically, the lower stretches of Malaysian rivers are characterised by heavy silt loads especially after heavy rains. For urban areas, Hj Keizrul bin Abdullah (2002) demonstrates that 90 % of sediment load in rivers are derived from land cleared for construction. For example, in the Klang Valley alone, it has been estimated that erosion averages 2,950 tons/sq. km/yr for the whole catchment, equivalent to about 3 mm of soil loss a year. In many upstream areas where forest clearance has been rapid, erosion rates of more than 50,000 tons/sq. km/yr are not uncommon (Wan Ruslan Ismail, 1995; Chan and Wan Ruslan Ismail, 1997). In comparison, the rates of erosion for undisturbed forest catchments are only of the magnitude between 10 to 100 ton/sq. km/yr. Hence, pollution via sedimentation is a serious problems for Malaysia rivers and a major river management issue (Douglas, 2002). Hj Keizul bin Abdullah (2002) further noted that although floods are often considered as natural phenomena, deforestation due to human activities have exacerbated flood frequencies and magnitudes, by increasing both the peak discharge and the time of concentration. For example, studies in Sg. Tekam (Malaysia) showed that with clearing of land from jungle to cultivated crops, the initial impact was a 157 % increase in water yield, a four fold increase in sedimentation rates and a 185 % increase in flood peak flow while time to peak increased by 65 %. However, when crop cover was established, these parameters declined but were still higher than the pre-clearance stage.

2.0 Flood Management in Malaysia

2.1 Introduction

In Malaysia, more than about 10 % of the country is flood-prone affecting more than 3 million people. The annual flood loss potential is about US$26.3 million. Despite this, flooding is good for padi farming, as the monsoon season brings rain and floods (flooding replenishes the soil with rich alluvium). Hence, flood plain occupants in such areas are well adapted to floods. However, the occurrence of flood hazards in urban areas, especially flash floods, is considered a sign of unsustainable development. This is largely due to rapid development (often haphazard) of urban floodplains such as those in Georgetown, Kuala Lumpur and Kota Bharu (Chan, 1995). Rivers have been mismanaged to the extent that river reserves are totally destroyed (Chan, 2002a). The replacement of natural forests with impervious urban areas result in almost all the rainfall entering the rivers in a shorter time. This reduces the capacities of most rivers to drain away excess water. Rivers in urban areas are very constricted and development literally comes to the rivers' doorstep, i.e. up to their banks. There is no buffer zone or river reserve leaving rivers no room to manoeuvre. Hence, reducing their drainage capacities. Furthermore, rapid urbanisation of urban floodplains and upstream development of hill land have changed surface characteristics and altered the hydrological cycle, particularly the time in which rain drops enter the rivers and the volume of runoff (Chan and Wan Ruslan Ismail, 1997). Hill land development is a form of unsustainable development which often results in accelerated soil erosion and landslides, two forms of environmental hazards. Soil erosion leads to sedimentation and siltation of rivers, contributing to increasing flood hazards of more severe magnitudes. The literature of flood hazard studies indicate that it is the negative interactions between the natural process system and the human use system that generates environmental deterioration and hazards such as floods (White, 1945; Burton et al., 1993; Chan, 1995).

Rapid development in Malaysia and many developing countries, some over centuries and some over many decades, have systematically destroyed and decimated forests and wetlands (including the lakes which they surround). This has manifested itself in an ugly way as floods took a heavy toll on the environment and human populations, who have settled on floodplains which were once rich and diverse wetlands (Cai et al., 2001). Some of the more severe flood in recent decades have been linked by scientists to the replacement of wetlands with agriculture, industrial, urban and other forms of human land use which are incompatible with the environment. Malaysia's own growth in the last decade is nothing short of phenomenal. For example, the rate of economic, industrial, infrastructural and urban developments during the last two decades has been rapid, especially during the last half a decade. From the late 1980s to 1997, the Malaysian economy has experienced an average GDP growth rate of about 8 per cent per annum. In 1989, 1990 and 1995, the corresponding GDP growth rates were 8.8 per cent, 10.1 per cent and 9.3 per cent respectively. Guided by the Malaysian Government's so-called Vision 2020 Strategic Plan, the country is poised to become a fully developed country by the year 2020. Current trends indicate that Malaysia will, at least in the short term (over the next decade or so) enjoy the same rate of growth. However, against this background of rapid economic development and the active pursuit of industrialisation, the country's finite resources (especially its forest) and fragile ecosystems are being threatened. This has led to the frequent occurrence of environmental disasters, most notably floods and associated landslides.

Thus, in its frantic quest for modernisation and industrialisation, Malaysia is experiencing increased incidence of flooding, largely as a result of over-zealous rapid development without stringent environmental protection measures. This is a common scenario in many developing countries, including Malaysia, whereby the desire for rapid economic development in order to catch up with the developed world is often over-emphasized and has led to an unbalanced development strategy which often sacrifices environmental principles purely for the sake of economic gains. Noble principles such as reducing the greenhouse effect, curbing ozone depletion, controlling environmental degradation, forest regeneration and sustainable development are often talked about and championed by many developing countries in their negotiations with the developed world. Malaysia organized and initiated the Langkawi Declaration in 1991 and championed the rights of the developing world in its fight against the super-powers on the issue of greenhouse gas emission and global warming during the 1992 Earth Summit in Brazil. Malaysia's commitment towards environmental protection is clear, as there are policies, laws, regulations and EIA requirements in developments which can have an effect on the environment. Unfortunately, however, despite this commitment (and its international stance against environmental degradation), many aspects of Malaysia's environment on the local front is still being exploited and degraded by irresponsible parties. These are but a few of the salient examples of classic environmental degradation resulting from human miscalculation and mismanagement of the forces of nature. Although many, notably politicians, have claimed that the majority of flood hazards and disasters are the result of natural causes or even "Acts of God", their frequent occurrence coupled with increasing awareness and improved education amongst the public have made such claims less and less tenable. Despite the fact that such incidents have their origins in the forces of nature, the Malaysian public now demands accountability and many are convinced that such hazards are probably more due to "Acts of humans" rather than "Acts of God".

- **Flood Management Strategies**

In terms of management, science and technology are eagerly employed in flood mitigation. New technological innovations are routinely used and the Malaysian official approach to flood mitigation has always been in line with a technological approach via the application of new technologies such as the use of remote sensing in flood forecasting and telemetry and automatic warning gadgets in flood warning and evacuation systems. For example, remote sensing technology using satellite pictures, radar imageries and aerial photographs is being applied to monitor and predict floods. High-tech computer modelling is also employed in this area. Undoubtedly, such developments, if applied properly can effectively reduce loss of life, livestock, crops and property damage. However, the application of high-tech solutions is only one side of a coin. These technologies can only be successful if the other side of the coin, i.e. the public/victims respond effectively to flood warnings and react positively. Often, sophisticated (imported) flood warning and evacuation systems (FWESs) are alien to the public who are accustomed to traditional FWESs. Hence, if the public are not properly coached and briefed about the new FWESs, then there are bound to be skepticism, confusion and even inappropriate responses. This will eventually lead to lack of confidence in the costly new technologies, rendering them utterly useless (Chan, 1997). In many cases, such confusion and mistrust of the new systems have even led to greater flood loss as in several cases of mistrust of the solar sirens in Georgetown (Penang State) and Kampong Dato' Keramat (Kuala Lumpur). In contrast, traditional FWESs have been employed for centuries and the locals understand them well as they are used to them. Because of their long adaptation, locals respond effectively in times of flooding via traditional systems in much the same way as the human body's immune system responds to an alien strain of virus. Take away this traditional system and replace it abruptly with a completely new system will do the victims more harm than good, as it will probably endanger their lives.

In Malaysia, the. government is expected to be the sole provider of flood protection. However, centuries of experience of living with floods have made the majority of Malaysians "flood-wise". Hence, the majority of flood-prone victims living on the flood plains have developed some forms of flood mitigation and flood-loss reduction methods (Chan, 1995). Nevertheless, flood losses in Malaysia is severe (Chan and Parker, 1999). In Malaysia, official flood management is predominantly focused upon flood control measures classified as "Structural Flood Mitigation Measures", i.e. mostly on construction of large engineering structures to control floods. Unofficially, however, the public have evolved traditional measures to reduce losses as well as adaptation to floods. It is recognized by the flood authorities that a comprehensive method employing both structural and non-structural measures would be hugely beneficial. However, politics and economic considerations often significantly reduces the application of non-structural measures and this has limited overall effectiveness (Chan, 1999). Chan (2002b) has discussed in detail the many structural measures currently employed by the flood authorities in Malaysia. These include: River Improvement, Construction of Embankments, Tidal Gates, Urban Drainage Improvement, Diversion/Relief Channels, Underground Drainage, Retention Ponds, Installation of Water Pumps, Multi-purpose Dams, Flood-Proof Buildings, Bunds and more recently the emphasis on the construction of environmentally friendly drainage systems (http://agrolink.moa.my/did/river/stormwater/index.html 21 April 2004). Politicians favour structural solutions as they bring a high profile and seldom have the resilience to fight against businessmen or corporations.

Non-structural solutions to flood reduction are not new and refer those measures that do not require the construction of structures. Hence, they are non-engineering measures. They are less expensive than structural ones (which usually need heavy capital expenditure) and can be used to supplement existing structural measures. Many non-structural measures can also be quickly implemented as compared to the construction of dams and reservoirs which may take years. In Malaysia, there are many non-structural measures which can be applied effectively. Non-structural measures include Legislation, Gazettement of Forest Reserves, River Reserves and Parks, Freezing of Development on Environmentally Sensitive Areas (Hill Land, Flood-prone land, water catchments, area rich in biodiversity, etc), Public Education and Awareness Campaigns, Relocation of Riverine Communities, Demarcation of Green Belts or Buffer Zones, Application of Environmental Impact Assessment (inclusive of Detailed EIA and Macro EIA, Improvement of Flood Forecasting Systems, Improvement of Flood Warning Systems, etc. (Chan, 2002b) In addition, Traditional Flood Hazard Response Systems (TFHRS) are also non-structural systems. For example, Malaysians living in floodplains are accustomed and well-adapted to floods. Many riverine and floodplain dwellers have developed traditional adaptations and responses to reduce the effects of flooding. These responses have been effective but their extent is generally limited because they are fragmented and uncoordinated. However, by incorporating these traditional systems into official systems would greatly reduce flood losses. Hence, it is imperative that the flood authorities move

In recent years, realizing that conventional drainage which drains stormwater into drains and rivers under the "As fast as possible" approach has actually exacerbated flooding rather than prevent it, the Drainage and Irrigation Department (DID) has embarked on a new flood management approach. The conventional drainage system is based on the first urban drainage manual " Planning and Design Procedure No.1: Urban Drainage Design Standards and Procedure for Malaysia" was published by DID in 1975. This manual has been used as a guideline for more than twenty-five years and since its publication, although there have been many new technological developments in urban area. Conventional drainage system, unfortunately has led to increase the occurrence of flash flood at the downstream of the catchments. Additionally, open drainage invites more polluted river and therefore has worsened the quality of life in urban community. Therefore conventional drainage is no longer an effective measure in solving flood (Nor Azazi Zakaria et al., 2004). Due to this problem, Department of Irrigation and Drainage (DID) Malaysia is taking a proactive step by introducing New Urban Drainage Manual known as Storm Water Management Manual for Malaysia (Manual Saliran Mesra Alam or MSMA) (http://www.agrolink.my/did/). From 1st January 2001 onward all new development in Malaysia must comply with new guideline that requires the application of Best Management Practices (BMPs) to control stormwater from the aspect of quantity and quality runoff to achieve zero development impact contribution. These concepts of BMPs will be able to preserve the natural river flow carrying capacity.

One of the new strategies under the MSMA approach is the innovative "Bio-Ecological Drainage System (BIOECODS)" developed by the River Engineering and Urban Drainage Research Centre (REDAC) (Aminuddin Ab Ghani et al., 2004). Under this system, the Universiti Sains Malaysia Engineering Campus is set as a pilot project of an ecologically sustainable development in terms of urban storm water management. The concept, based on integrating storm water Best management Practices (BMPs) namely "Control-at-Source" approach, into urban planning and designed to achieve multiple objectives, is the most promising approach in newly developing or urbanizing areas. The main function of BIOECODS is to promote storm water infiltration from impermeable areas (e.g. roof tops, car parks) by using bio-ecological swales. The second function is to release gradually the storm water through the use of bio-ecological swales, on-line underground bio-ecological detention storages and bio-ecological dry ponds. Finally, the third function of BIOECODS is to enhance treatment of storm water quality using treatment train concept by utilizing bio-ecological swales and bio-ecological pond (e.g. wet pond, wetland) as the storm water moves downstream. In short, BIOECODS is an example of an innovative sustainable drainage system that will help restore the natural environment, maintain river flow, and control ground subsidence. By integrating storm water utilities with the green away and landscape, the drainage system will also enhance the Healthy Campus Concept in USM Engineering campus. The application of BIOECODS in a new development attempts to solve three major problems commonly encountered in Malaysia namely flash flood, river pollution, and water scarcity. It is hope that new developments in Malaysia will implement BIOECODS to achieve Department of Irrigation and Drainage (DID)'s aim of "Zero Flash Flood" by 2010 and help preserving the natural characteristics of the existing rivers in line with the national "Love Our Rivers Campaign".

In Malaysia, the time has come to discard expensive and ineffective structural mega flood mitigation projects (that take a long period to complete) in favour of cost-effective, practical and less time consuming "soft-engineering" methods such as MSMA and Bioecods. Environmentally-friendly drainage systems must be given priority and the MSMA made mandatory for developers to implement. In addition, rainfall harvesting (roof-top and ground storage) has to be incorporated into building codes and made mandatory for new houses. All newly developed areas should have a minimum percentage of permeable surface that allow rain water to seep through and be retained. The authorities should also pay more attention to non-structural flood management strategies as a complement to structural methods. Finally, in order that flood management be totally effective, all stakeholders, including victims, must take part pro-actively in terms of appropriate response, decision-making for flood mitigation projects, and actively support the authorities' new flood management approach of retention of water at source.

3.0 *Flood Management in the USA*

3.1 Introduction

In the USA, flood is the major natural hazard affecting a greater part of the country. During the 20th century, floods were the number-one natural disaster in the United States in terms of the number of lives lost and property damage (http://ks.water.usgs.gov/Kansas/pubs/fact-sheets/fs.024-00.html 15 June 2004). Major flood events in the 20^{th} Century in the USA are shown in Table 2. In the early 20^{th} century, flood management approach in the USA was focussed on heavy Federal policy of flood control technology based on the Flood Control Act of 1936. Hence, the majority of flood strategies encouraged reliance on control technology and discouraged or even given insufficient weight to other possible adjustments such as land-use regulation, flood-proofing, flood warnings, and emergency evacuation (White et al., 1958). The American experience illustrates clearly how a developed society is affected by and seeks to address the flood problem via both a top-down state control approach as well as complete individual freedom to choose individual flood response. In the USA, about 6-8 % of the country is affected by flooding as about 300,000 km^2 of land are located within the 100-year flood plain (Alexander, 1993: 141). As a result, it is estimated that 6.4 million structures are at risk to flooding, and 12 % of the population or 10 million households are living is flood-prone areas. In terms of property, US$390 billion are at risk to flooding (Priscoli, 2001). The average annual loss of life due to flooding is estimated at between 50 to 100 people while the economic flood loss is estimated to be around US$5.50 per head of the US population (Alexander, 1993:142).

It has been estimated that direct flood losses up to the 1970s in the United States averaged about US$1 billion (Burton et al., 1993:78). In 1972, the worst flooding occurred in the aftermath of Tropical Storm Agnes whereby 238 deaths and damages were in the millions. Flood damages continue to rise significantly over the decades. Arguably, majority of the most severe and widespread flooding occurs along the Mississippi River. Arguably, the Mississippi floodplain from the middle stretches to its delta have been densely developed over at least 2 centuries, if not more. In the last 10 years alone, there were three 100-year floods in 1993, 1998 and 2001.

Unlike in Malaysia which is only affected by monsoon, flash and tidal floods, the USA is affected by many different types of floods. The United States Geological Survey (USGS) acknowledges that floods are the result of a multitude of naturally occurring and human-induced factors, and defines floods as "the accumulation of too much water in too little time in a specific area". Many types of floods occur in the USA. They include regional floods, flash floods, ice-jam floods, storm-surge floods, dam- and levee-failure floods, and debris, landslide, and mudflow floods.

3.2 Flood Causes

The USA is probably one of the most developed countries in the world. It is arguable also one of the most urbanized. It is estimated that one sixth, or 26,400 km^2, of the country's flood plains are urbanized. This is arguably one of the main causes of flooding, especially flash flooding in urban areas. As is the case in China and Malaysia, removing natural vegetation and replacing them with impermeable surfaces have the undesired effect of increasing the volume of runoff, shortening lag time (time in which rain reaches the river), reduction of soil water recharge and groundwater flow, and almost zero retention and absorption by vegetation. All these contribute to floods of greater frequencies and magnitudes (Chan, 2002b).

The natural causes of flooding are due to warm weather conditions which generate active convection, storms and heavy rains. For example during 2001, severe flooding occurred along the middle stretches of the Mississippi, centred around the Quad City areas. Several strong storm systems allowed temperatures to warm markedly across the upper Mississippi basin, bringing with them warm temperatures, active convection and heavy rains (most of the rains fell in the upper Mississippi basin). The prolonged highly abnormal weather conditions also melted the deep snow pack across the upper Mississippi, releasing more surface flow to the basin. This brought about heavy flooding, although the National Weather Service in the Quad Cities had issued a River Flood Warning for the Mississippi River, from below Guttenberg (L/D 10) to Gregory Landing MO. Severe flooding followed thereafter, flooding Davenport and the riverine areas from the Quad City area to St Louis.

In the USA, regional floods occur seasonally as a result of winter or spring rains occurring simultaneously with snow melt. This will quickly fill river basins with too much resulting in flooding. As the ground may be frozen, almost all overland flow eventually ends up in rivers as soil water infiltration is limited. A good example of this type of flooding is the March 1936 New England flood in which more than 150 lives were lost and property damage estimated at around US$300 million. Most regional floods are usually associated with slow-moving, low-pressure or frontal storm systems including decaying hurricanes or tropical storms. Persistent wet meteorological patterns are usually responsible for very large regional floods such as the Mississippi River Basin flood of 1993 wherein damages were US$20 billion (http://ks.water.usgs.gov/Kansas/pubs/fact-sheets/fs.024-00.html 15 June 2004).

Because of early colonization, the majority of US cities are located on river banks or on flood plains. As the cities expand, flood plains and river reserves were encroached upon, resulting in not only constriction of river but also greater exposure to flooding. Hence, another main cause of flooding put forward by scientists regarding the occurrence of more frequent floods with greater magnitudes (i.e. about the occurrence of three 100-year flood with a period of just 10 years) is the fact that of floodplain encroachment, one of which is the building of levees thousands of kilometers long. In the USA, levees were a preferred method of flood control. The era of levee building started in the mid-1800s when the Swamp Act was passed. This act allowed for the development of swamps and wetlands, which were then regarded as "waste lands" without any significant functions. This act entailed the sale of 65 million acres of "swamp" for as little as $1.25 per acre in 15 Southern and Midwestern states, but in the years that followed, thousands of hectares of swamps and wetlands were bought and developed. This reduced the important hydrological functions of wetlands, one of which was the retention of large quantities of water. Without the wetlands, excess water from rain and in the river over flowed the banks and flooded the adjacent plains. The Swamp Act saw a period of rapid development of such land in which the intensive conversion (and destruction) of wetlands (including swamps, ox-bow lakes, ponds and marshes) destroyed them. Levees were built to capture wetlands and swamps from the rivers that feed them, and turn them into productive agriculture as well as for urban and other development. Hence, the Swamp Act was good news for developers but it is one of the main reasons for the exacerbation of flooding.

Development along rivers, especially construction activities, contribute to sedimentation and siltation of rivers. This causes the shallowing or rivers and a reduction in their drainage capacities. In addition, urban development near rivers allow garbage to be dumped into rivers from domestic households to factories to offices and waste treatment plants. We don't much care about a flood if all the river does is spread out into its natural floodplain, as long as there's nothing but floodplain there. But 10 million people now live in floodplains in America. So not only have we increased the likelihood of flooding, but we've put ourselves in harm's way so that when the floods come along, they do more damage.

Land use change from natural vegetation to urban is another main cause of flooding – viz. flash floods. Generally, flash floods are characterized by a steep hydrograph with the peak discharge attained in a matter of minutes after the commencement of rain. Theoretically, a flash flood can occur within several seconds to several hours, with little warning. Flash floods can be deadly because they produce rapid rises in water levels and have devastating flow velocities. Besides the change from a permeable surface (e.g. forest) to an impermeable surface (e.g. asphalt), there are other factors that also contribute to flash floods. These include the occurrence of intense storms (e.g. thunderstorms), high rainfall intensity, saturated soil conditions, long rainfall duration, poor drainage, low-lying topography and slope of the receiving basin. The occurrence of "bottle-necks" in the drainage system (as when two rivers converge) can also lead to flooding. Flash floods occur most frequently in urban areas because of the high percentage of impervious artificial surfaces such as asphalt, cement, concrete, tiles, tarred streets, roofs, and parking lots where runoff occurs very rapidly. However, in some hilly areas, flash floods also occur when the steep slopes surround a narrow valley or canyon. In fact, floodwaters flowing down steep slopes are rapid flowing and can cause the floodwave to move downstream at a very rapid rate and this means victims have little time to act or escape. For example, a flash flood caused by 380 mm of rain in 5 hours from slow-moving thunderstorms killed 237 people in Rapid City, South Dakota, in 1972. In addition, some floodwaves (due to heavy upstream rainfall) appear to occur in areas (downstream) that are not raining. Such floods catch people by surprise, resulting in heavy casualties and damage. In the USA, deserts also experience flash floods, as occasional thunderstorms produce rapid rises in water levels in otherwise dry channels.

In winter or in the glacier areas, rivers are totally or partially frozen. In these rivers, a rise in temperature or increase in river level may break up the frozen river resulting in blocks of ice and snow moving downstream. When the ice and snow pile up on a narrow channel, shallow riffles, bridge piers or a sharp meander, the ice and snow form a frozen dam across the channel over which the water and ice mixture continues to flow. As more and more ice and snow pile up, more and more water backs up upstream from the ice dam. This causes a sharp increase in river level upstream of the jam resulting in flooding in the vicinity of the ice jam. This kind of flood is dangerous as the water temperature is close to freezing. In addition, when the ice dam breaks, a floodwave is created and moves downstream rapidly. The high energy caused by the floodwave causes massive damage to structures such as bridges and roads. For example, ice jams on the Yukon River in Alaska contributed to severe flooding in the spring of 1992.

In coastal areas, storms can push waves inland. This is known as the storm-surge flooding. Low-pressure systems and hurricanes can create storm-surge flooding. The storm surge is unquestionably the most dangerous part of a hurricane as pounding waves create very hazardous flood currents. Generally, nine out of 10 hurricane fatalities are caused by the storm surge. In the event of a storm surge occurring simultaneously with a high tide, the flooding can be disastrous. An example of a storm surge flood is the September 1900 flood, caused by hurricane and storm surge at Galveston, Texas. This event killed more than 6,000 people, making it the worst natural disaster in the United State's history.

3.3 Flood Management Strategies in the USA

In the history of flood plain management in the USA, from the 18th century to early 20th century, the flood management approach was based on the employment of small scale structures to tackle a local problem. It was only during the mid-20th century that the Federal Government came onto the scene and took the lead role via the employment of large structures to control floods. However, as pointed out by White (1945), intensive government expenditure did not have the desired effect of reducing floods. Hence, in an about turn, the later part of the 20th century saw the move back to use local expertise and the combination of large and small structures as well as the employment of non-structural measures (Priscoli, 2001). Hence, in the 1800s, the strategy used was one of "flood prevention". In the early 1900s, it was a strategy of "flood control" while in the mid-a900s it was a strategy of "flood reduction". Finally, the later part of the 1900s until now is characterized by a strategy of "flood plain management" (FPM). According to Priscoli (2001), FPM is a continuous decision-making process that aims to achieve the wise use of the Nation's flood plains. This process should involve all stakeholders including owners, businesses, government officials (at all levels), farmers, developers, flood victims, etc. The decisions made must take into view the viability of the projects in the short, medium as well as long term. And all decisions must include a cost and benefit analysis of the project and its options. Naturally, a top-down approach is still very much needed as Federal funds are necessary for effective FPM. Hence, one of the main principles of FPM is that the Federal Government should hold major interest while the basic responsibility still lie with state and local governments. Another principle is that flood plains must be seen in terms of the total community, regional and national planning and management.

One of the first strategies was that of the levee. By 1727, New Orleans was protected by a 1.3 metre embankment. In 1543, it was also noted that Indians built mounds as high as they could as a form of flood-proofing their houses. The Flood Control Act 1917 came into effect, involving the lower Mississippi River and Sacramento River. After the massive 1927 flood, the Flood Control Act of 1928 came into effect. The Department of Agriculture was to work upstream while the Corp of Engineers worked downstream. However, there was little co-ordination. Between 1936 and 1952, US$11 billion was spent on flood control projects. The idea was "To build a way out of the problem". During the 1940s to 1960s, a broader view to flood management was emerging from the works of Gilbert White and Harlan Barrows (White, 1945). It was realized that the root of the problem perhaps lies in settlement and cultivation of flood plains. In 1953, the Tennessee Valley Authority (TVA) was formed and this marked the first time when land use management was used in tandem with flood control measures (e.g. dams). In the 1950s and 1960s, the move was towards greater water resources co-ordination incorporating integrated basin management of water resources. In 1968, the Flood Insurance Act gave victims greater security. In 1976, the National Programme for Flood Plain Management was submitted to the President. In1979, there was a revision to the programme to raise natural and beneficial values of flood plain. The 1993 Mississippi flood initiated the full consideration of all possible alternatives (evacuation, warning, proofing, natural and artificial storage), full weight to social-economic and environmental values, and finally more non-structural measures in order to reduce vulnerability.

There is now greater awareness of floods and the alternatives to manage floods. Increasingly also, there is greater awareness that wetlands play an important hydrological function and must be conserved as natural means of flood control. Hence, floodplains with wetlands, allow excess water during heavy rain storms to spread out before entering a river. Wetlands act like sponges as they soak up a large quantity of the water. Wetlands also absorb a lot of water down into the ground, as much as 1.5 million gallons per acre, depending on the nature of the soil. Not only that, during the dry season, wetlands release the water and maintain river flow. During the wet season, wetlands retain and hold the water and release it slowly. Hence, despite the fact that between the Swamp Act and other sales, an estimated 120 million acres of floodplains have been destroyed in the USA (i.e. only 50 % of what existed 200 years ago), the US authorities are now embarking on a plan to conserve existing wetlands and at the same time plant human-cultivated wetlands. In upstream areas, forests area also being conserved as national parks, wildlife reserves and water catchments. This is another important land use strategy to manage flood plains and reduce flooding.

Furthermore, improved GIS, use of remote sensing, GPS and other high tech tools have given better forecasts of floods and flood warning. This has further reduced the loss of lives and total flood damage. There is also less Federal emphasis on structural approach although the payments given out for disaster aid by the government has increased significantly. Increasingly, the government is encouraging greater institutional coordination by integrating the government sector with the private sector, local communities, state and federal agencies. The public is encouraged to take up flood insurance to reduce their losses, install flood-proof structures, seek flood advice, and work in local flood response societies. There is also greater understanding of flood warning signals, evacuation plans and disaster response scenarios. All these combine to reduce loss of lives and property damage.

4.0 Flood Management in China

4.1 Introduction

As one of the earliest civilizations in the world, China has had a long history of floods dating back to 30 BC with successive dynasties and ruling governments pre-occupied with attempts to control the disaster (Beck, 2000). An analysis by some of NOAA's top flood experts identified many extreme flood events that they considered some of the worst of the 20th century (NOAA Online, 1999). In China, floods usually occur in the middle and lower reaches of the major rivers, notable the Hwanghe (Yellow River) and the Yangtze River. Historically, major floods that occurred on a recurring basis associated with heavy rainfall events have killed from several thousand to several hundred thousand people. In the 20th century, major flooding disasters occurred in 1900, 1911, 1915, 1931, 1935, 1950, 1954, 1959, 1991 and 1998 mainly in the Yangtze River Valley. For example, the summer flood along the Yangtze during July- August 1931 was considered the most severe event in the 20th century, with over 51 million people affected (1/4 of China's population), and 3.7 million people killed – mostly from disease, starvation or drowning. In recent years, floods in 1996 and 1998 have affected South-east and central China, mostly along the Yangtze river (CNN Beijing, 5 Aug 1996; CNN 6 July 1998; Leitner, 1999).

In the early part of the century, it was already obvious that over-clearing of upland forests and mid and downstream wetlands have contributed significantly to flooding. For example, the Yangtze River Flood of 1931 epitomised the effect of land use change from forest and wetlands to agriculture. This summer flood along the Yangtze during July- August 1931 was touted as the most severe, with over 51 million people affected (about a quarter of China's population) of whom 3.7 million were casualties of this notorious disaster (often regarded as one of the great disasters of the 20th century in the world). Most people died of drowning during the flood and also due to disease and starvation after the flood. Apparently, the 1931 flood was preceded by a prolonged drought from 1928 to 1930 which was also partly accountable for destroying forests and wetlands. Once the wetlands became dry, the conditions became irreversible as vegetation wilted and died. Hence, reducing the wetlands' absorptive and water retaining properties.

The Yangtze floods of 1998 illustrates the degree to which humans have decimated the environment, particularly with respect to wetlands destruction. A report from the United States Embassy in Beijing quoted that sharp declines in natural reservoirs such as forests and lakes, increased silting of rivers and lakes from the de-treed lands in the Yangtze basin, and steady encroachment on river beds by Chinese farmers have combined to push the flood waters to record levels during the 1998 Summer floods. The report further stated that although the Yangtze River flow rates in 1998 were below historic highs, the flood levels were setting record highs because of silting due to forest and wetlands clearing. Satellite photographs taken over the past decade show increasing numbers of land-poor farmers moving into the most flood-prone areas. The encroachment by farmers onto natural flood holding areas such as wetlands, lakes and even river beds is, like the encroachment of the cities onto farmland, an important problem in the formulation, regional coordination and enforcement of land use policy. Clashing local economic interests, corruption, and poor coordination and communication combine to make land use planning and enforcement difficult.

An August 14 article in Southern Weekend, an outspoken newspaper sponsored by the Guangdong Communist Party, argues that China has frequent flooding because flood dikes and reservoirs are built to counter only floods that might come once ever ten to twenty years, a far lower standard than in the U.S. and Japan. The State Council on August 5 issued an emergency order called for an immediate halt to all illegal forestry and a one year moratorium on all conversion of forest land to other purposes. A USD 2 billion five-year reforestation program is intended to reduce soil loss on the upper reaches of the Yangtze and Yellow River and so reduce silting at the Three Gorges and Xiaolangdi dams as well as flood risk. In addition, the state timber company work force will be cut by one million workers and a wood production will be reduced by 10 million cubic meters. Chinese wood imports may double as a result. Many Chinese scientists now believe that the very heavy rains, flooding and La Nina climate abnormalities of 1998 are related to global climate change. Lessons drawn from the floods of 1998 may well come to affect Chinese priorities in matters such as environmental protection and climate change.

4.2 Flood Causes

Though severe flooding often occurs in China over the centuries, the flooding in recent decades have been increasing severe. The most densely populated ten percent of Chinese territory which produces 70 percent of its agricultural and industrial product lies below the flood level of China's rivers. Long-term environmental deterioration over the past 50 years has increased the threat of flooding, and largely contributed to the severe floods which have already killed over 2000 people in Hubei, Hunan and Jiangxi provinces this year. Widespread excessive cutting of trees since 1949 has reduced natural water storage capacity and increased the soil run-off into rivers. During the 1950s the forest cover of Sichuan province fell from 19 percent to about 6.5 percent and tree cutting was over double the natural tree growth rate. The backyard steel furnaces of the Great Leap Forward of the late 1950s consumed some of these trees.

Destruction of wetlands and other forests have given rise to siltation which made rivers shallow. Hence, even when discharge is less a bigger flood occurs. This is a classic case of "Less Water But A Bigger Flood". Zhuang Guotai of the State Environmental Protection Agency Ecological Section told Worker's Daily in early August that for every 70,000 hectares of forest that is lost, a natural reservoir that can store one million cubic meters of water is lost. Zhuang said that although the peak flow rate of the Yangtze at Yichang this year is below historic highs. Twenty-three years have had higher flow rates. But the destruction of forests resulted in natural water storage loss and silting of rivers and lakes and raised the level of the river further. The encroachment of land-hungry farmers on lakes reduced the capacity of the environment to absorb flood waters. Dongting Lake, a major regulator of Yangtze floods, shrunk from 6000 square kilometers in 1700 to 4350 square kilometers in 1949 and by another third to just 2820 square kilometers by 1980. [see articles "Heaven Should Not Get All the Blame for the Floods" and "Control the Waters" on the U.S. Embassy Beijing web translations subpage at http://www.usembassy-china.gov/english/sandt/sandsrc.htm. The Southern Weekend article is translated on the Embassy website and can be found in Chinese on the Nanfang Ribao web site at http://www.nanfangdaily.com.cn, subsection Nanfang Zhoumou]

Research has shown that silting has contributed to lifting river bottoms above the floodplains where cities and other settlements are located. Hence, all along the Yangtze, the river bottoms are actually higher than the surrounding cities. Increased silting deposits 150 million tons of mud on Hunan Province river and lake bottoms each year. The bottoms are one to two meters higher than they were in 1949. Some Chinese say that the increasing amount of silt in the now often yellow-colored Yangtze owing to greater soil run-off has made the Yangtze China's second "Yellow River". More silt and less water storage capacity in the Yangtze river basin means that even with less water floods can become more serious that ever before. In mid July at Kaifeng, Henan Province, ESTOFF learned of this phenomenon at work on the lower Yellow River. At Kaifeng the bottom of the Yellow River is now 20 feet above the city of Kaifeng. Naturally the Yellow River dikes at Kaifeng are higher than this since the water level is even higher. Silting makes floods much worse. For example, the 1958 Yellow River floods crested at a flow rate of 22,300 cubic meters per second. Nearly forty years later, in 1996, after silting had raised the river bed by 90 centimeters, a crest of 7600 cubic meters per second, just one-third the 1958 flow rate, but even so, the water reached the highest level ever. Once several Yellow River dikes broke under the strain, 3.43 million mu (230,000 hectares) were drowned and over one million people were harmed by the disastrous 1996 Yellow River flood.

Another reason for increased flooding is the fact that land hungry-farmers have been (and are still) converting wetlands into agricultural land. At both the central government and local administrative levels, land use planning is weak and enforcement is often lacking. A Chinese environmental scientist told ESTOFF in Spring 1997 that studies of satellite photographs over the past 15 years show a rapid increase in the number of people living in areas most vulnerable to flooding. Farmers faced with a declining amount of arable land- available per capita are increasingly encroaching on lakes and riverbeds. Balancing the interests of land hungry farmers with the need to protect against flooding is a difficult question of land use policy formulation, regional coordination and enforcement. In early 1997, satellite photos revealing that urban encroachment on China's scarce agricultural land was three times higher than official statistics shocked Chinese leaders, resulting in a stern State Council order that froze land transfers and called for the formulation of detailed land use plans by local governments. Throughout China land use plans and maps are being developed in order to monitor compliance and to enforce the State Council order. Land use policy formulation and enforcement are critical weaknesses in Chinese environmental policy.

The encroachment of farmers and local governments upon rivers and lakes has many similarities to the encroachment of cities on farmland. One example is how the Huarong County, Hunan government in May, 1992 tore down one kilometer of dikes in the name of opening up new agricultural land. The result, according to the China Green Times, was that 80,000 hectares of farmland and 700,000 people lost their protection from flooding. An effective land use policy would depend upon the central government's ability to reconcile sharply differing interests. The poor quality of statistical data, widespread corruption, the central government's limited information about local situations and what some see as the decreasing willingness of local governments to obey central government directives will make effective land use policy formulation and enforcement difficult. (see for example, translations of recent Chinese press articles on these topics at http://www.usembassy-china.gov/english/sandsrc.htm. For the difficulties of coordination between the central and provincial governments, see the "Fading of Environmental Secrecy" and "PRC Air Pollution: How Bad is It?" on the Embassy Beijing EST section main page at http://www.usembassy-china.gov/english/sandt/index.html)

Some PRC press commentary has highlighted low spending on flood prevention infrastructure. In the August 8 issue of South China Weekend [Nanfang Zhoumou], an extremely popular and influential newspaper sponsored by the Guangdong Province Communist Party Committee, the low design standard of Chinese river dikes was questioned. According to the report, Chinese river dikes are designed to withstand the largest flood that might be expected to occur over a ten to twenty year period while in Europe, Japan and the United States, a 100 - 200 year flood standard applies to large rivers and a 50 - 100 year standard might apply to other rivers. The Chinese standard is calculated by comparing the cost of avoiding flood losses versus that cost of building massive dikes and reservoir areas to control flood waters. This formula, according to the report, does not adequately reflect losses to the national economy and to the people of the region.

Like the Mississippi basin, the raising of dikes along the Yangtze has also given rise to a false sense of security and caused various other problems. The China Green Times [Zhongguo Luse Bao] on August 11, 1998 wrote that the dikes along the Yellow River can withstand a sixty year flood but that the Yangtze dikes have a much lower standard of withstanding a 10 - 20 year flood. The storage capacity of Dongting Lake, a large natural storage area for Yangtze flood waters, has sharply decreased due to silting which raised its bottom 1.7 meters between 1969 and 1996 as well as encroachment by farmers. According to the China Green Times reports that considerable investment in flood prevention at Dongting Lake over the last few year has raised the standard there from a 3 - 5 year flood to a five to ten year flood, this is still far too low.

Destruction of wetlands not only increases floods but also increases the incidence of low flows and water shortages. Several sections of the Yellow River have dried out completely for as long as 100 days. The lengths of these dry periods has increased steadily over the past decade. The cause is a decrease in river flow attributed to extensive deforestation and grasslands desertification upstream, especially in Qinghai Province, the source of half the Yellow River waters. A report in the March 31 People's Daily noted that the quantity of Yellow River water leaving the river source in Qinghai has fallen by 23 percent over the past nine year. The Governor Bai Enpai of Qinghai Province told reporters, "We can't keep up with the speed of the deterioration of the environment. We very badly need help from the State and the people who live in the Yellow River valley." [see Embassy translation of the March People's Daily article at http://www.usembassy-china.gov/english/sandt/qhaiylriv.htm] With the loss of tree cover, the natural reservoir capacity of the trees to store water that might otherwise be lost to evaporation or rush rapidly downstream is lost. Thus arises an apparent paradox: trees increase the total annual flow of a river but reduce peak flow during floods. Trees also help anchor soil that otherwise would wash into the river and so raise the height of river beds and flood levels.

It has also been alledged that illegal cutting of forest by local Government authorities is fairly common. Illegal cutting of forests, including in nature preserves, by timber companies operated by local governments occurs throughout China. These illegal operations by local government are one factor behind the environmental degradation that has worsened the flooding. Many local governments depend upon forestry for as much as 90 percent of their revenue. Local government timber companies often disregard frequent State Council orders as well as the criminal provisions on forestry provision of the new PRC Criminal Code which went into effect on October 1, 1997. [Note: the forestry provisions are discussed in "The Environment Enters the Chinese Criminal Code" on the Embassy Beijing EST web page] Although Chinese environmentalists have discussed flagrant violations with Embassy officers, only recently (as in the July 14 Beijing Youth Daily) have these violations by local government been reported in the press. For example, the summer 1996 student trip to save the Golden Monkey habitat in Deqin Prefecture, Yunnan Province was widely praised in the Chinese press, but the fact that it was the local government-owned timber company that did clear-cutting in a nature preserve went unreported. In China, government is changing, albeit slowly towards integrated development encompassing environmental conservation. However, not many will follow the example of Prime Minister Wen Jiabao of China who suspended plans for a massive dam system on the Nu River that scientists have warned could ruin one of the country's last unspoiled places (New Straits Times, 11.04.2004).

4.3 Flood Management Strategies in China

The department of water conservancy in China has committed significant funds to ensure the safety of banks, the control of rivers, the blocking of incoming water from upper reaches, and the construction of flood diversion systems, drainage sluices, and middle/small reservoirs in order to control floods. However, due to the comparatively low standards of design and construction, the water conservancy projects are not suited for the intensity of local disasters. For example, the current flood defense projects in Jianghan plain can generally defend the strongest floods in 10 years, and these banks are usually built upon the surrounding dikes, which are generally not strengthened (Cai et al., 2001). One of the popular flood control measures is the use of dikes. However, the dikes are prone to leakage and often break because of their layered sandstone structures. Therefore, it is not a very effective method to defend against floods. From the perspective of continuous development, it is recommended that a new and effective strategy of defense that combines the defense of flood disasters with the conservation of forests, protection of the environment, and the protection of the biosphere.

In essence, flood management needs to combine both ecological conservation with engineering measures. The engineering measures include many and are direct strategies to defend against flood disasters. Cai et al. (2001) have suggested many recommendations as follows:

- Construction of diversion and draining channels on the banks of major rivers, such as building a high canal on the plain to release the excessive flood discharge;
- Maintenance and enlargement of reservoirs in the marshes along the banks of major rivers to counteract the flood flow and the impact of flood to the banks;
- Increasing the height and the strength of the banks to allow small ascendance of the flood level and to increase the relative falling of water level during the flood flowing;
- Controlling the incoming water from tributaries. For example, the 3-gorge reservoir will be of great importance on the Yangtze River. When the reservoir is constructed, floods that resulted from storms in upper reaches will be effectively controlled, which will strengthen the defending ability of tributaries from current 10-year maximum to 100-year maximum. Combined with temporary diversion, breakage of river banks can be prevented and the safety of many riverine cities such as Wuhan be protected.

In terms of ecological measures, the emphasis is on such concepts as the establishment of an ecological environment, multiple coordination, a distribution according to the locations, an optimal production structure, the proper utility and protection of water and land resources, the maintenance of ecological environment, and the ability to defend against the impact from the environment. Based on past experiences, the following points are recommended:

(i) An adaptive ecological development combined with the industrialization of agriculture is the ultimate route to effectively alleviate and defend against flood disasters. Wetlands such as the lake district in the

Jianghan Plain consists of marshlands of various sizes and shapes. These wetlands must be conserved at all costs. Currently, the lakes and adjacent wetlands are shrinking due to agricultural encroachment. In addition,. many crop fields cultivated from these marshlands are yet to be equipped with basic field water conservancy systems. Once the floods come, the marshlands will be flooded and serious losses will result. It is recommended that a three-dimensional ecological agriculture be established according to the characteristics of marshlands, so that an upward marshland cultivation sphere, a rice-fish co-existing sphere, a rice sphere, a watered dry crops sphere, and a garden economic sphere be formed. Currently, good economic, ecological and social benefits have been achieved in the river district in Four Lake area and Xinxingyuan areas. In the other wetlands and lakes, such a system can be applied. For example, in the recent exploration of Hong Lake, Lantian Corporation, as the main body, has motivated the surrounding villages and families to achieve significant profits by utilizing the organism resource in Hong Lake water system through collaboration, on the basis of ecological protection. They not only pioneer in the ecological industrialization of agriculture through the combination of cultivation, process, trade, industry, and agriculture, but also provide the experience of solving the flood disaster problems in this area.

(ii) Due to the unbridled woods felling on the upper reaches of many rivers, the losses of water and soil deteriorate. The increase of incoming sand in rivers results in the sedimentation on the bottom, which raises the flood water level in many rivers yearly. Therefore, in order to enlarge the area of flood flowing section in the river, it is vital to forbid the unbridled felling in the upper reach areas, enlarge the cultivated woods area, slower the formation of flood flows, and decrease the incoming sands. It is heartening, therefore, to note that the Chinese authorities have banned logging in the upper reaches of the Yangtze River after the 1998 flood. This should be made a permanent ban.

There is also a need to construct a flood monitoring and warning system for the major river basins. For example, a monitoring system for natural disasters in Jianghan plain can be used to quickly and accurately transmit the information of the change of disasters to the departments of strategy and leadership, and to provide reference for the leaders to make decisions in the combat against flood disasters. Currently, the monitorial network for disastrous weathers is not ideal in Hubei Province. A number of automatic rainfall stations and automatic weather stations are much in need, so that the quantitative measurement of the average accumulation of precipitation in the upper reaches and main branches of Yangtze River can be applied. Thus the flood-causing rainfall information during flood periods can be monitored continuously and effectively, the forecasts of water level and flowing amounts of rivers can be provided more directly and effectively, and image, data, and pre-warnings can be sent to the governments and flood related departments automatically and timely. In the meantime, collaboration between different departments and professions should be well coordinated and organized. It is suggested to apply the modern technical method 3S (short for Spatial orientation, Satellite or shuttle-loaded remote sensing, and System of geographical information) for the construction of the dynamic tracing monitorial system and database for flood disasters in Jianghan plain. Currently relevant departments in Wubei Province (such as the meteorological center, the earthquake center, the China Science Insititution at Wuhan, Wuhan Technological University of Survey and Map, National Geography University) have had considerable technical capability and research facilities for the collaboration.

Finally, flood loss needs to be scientifically evaluated. Currently, flood loss assessment is carried out by local government or departments. This is not acceptable as the assessment is often inaccurate and biased. As the flooding in the Yangtze and Hwang Ho is extensive and commands international attention, it is imperative that the flood loss assessment be carried out by the national government with perhaps overseas assistance. It is recommended that an overall flood disaster risk index be created, as well as the creation of various comparable evaluative indices. There should also be a standardized system that can be applied in inaccessible districts where the assessment can still be carried out by the local authorities. There should also be an evaluative model, a disaster database, and a pre and post disaster evaluation of a flood disaster so that lessons can be learned and future losses minimised.

5.0 Conclusions

In the modern world, no one can run away from using technology to solve problems and this includes floods. While there is a need to incorporate traditional flood reduction mechanisms into official flood management strategies, it is envisaged that traditional mechanisms will not be significant at the national level or when a large flood occurs. Rather, such mechanisms will be effective during small and localized flooding where the magnitude, duration and extent is small. In all three countries discussed, it is envisaged that structural flood management measures will continue to be the predominant mode of flood reduction measure. This is more so in the case of China and Malaysia where the mega flood control projects (such as dams) are not only needed to control floods but are also vital to generate jobs, keep the economy running and provide irrigation to cultivate the food crop needed. In the case of the United States, non-structural measures and individual action may be predominant now that the government has adopted the approach to minimize large scale structural projects.

However, due to increased environmental awareness and greater levels of education, environmental measures to manage floods are envisaged to become important in all three countries. For example, there is no doubt that wetlands are nature's way of controlling floods as they influence the hydrological cycle by intercepting rainfall at the canopy and regulating the flow of rain down branches, trunks and roots before reaching the river. Wetlands act like sponges soaking and absorbing a lot of water down into the ground and then releasing it slowly over time. Hence, governments in all three countries at all levels have taken action to stop illegal cutting of wetland forests and other forests to curb flooding. In China, the PRC State Council, seeing the clear connection between clear cutting and soil loss upstream and the Yangtze River floods, on August 5 issued the emergency order "Protect Forest Resources, Stop Forest Destroying Agricultural Development and Illegal Occupation of Forest Land". In Malaysia, wetlands have been designed as Ramsar sites and many are vying for designation (Chan, 2003). There are plans to conserve as well as gazette wetlands not only as flood control mechanisms but also as wildlife sanctuaries, national and state parks, ecotourism sites, water catchments, and a host of other natural functions. In the United States, it has also been recognized that wetlands are extremely important in containing floods. Many plans have been devised to conserve wetlands along the Mississippi and other major rivers.

More importantly, a programme of reforestation of wetlands must be implemented. This will not only reduce flooding but in the long run reduce timber imports (when replanted forests are harvested sustainably) and also have benefits for reduction of CO_2 emissions as wetland forests are a source of CO_2 sequestration recognized by the IPCC. In China, the lessons drawn from the Yangtze floods make more likely the success of a five year US$2 billion massive reforestation and timber production cutback plan. This plan is now in full implementation. Accordingly, the plan would sharply reduce timber cutting by state timber companies, including areas of southwest and northeast China where the last old growth forests are now being cut. Reforestation would not only reduce flooding, there would be important advantages for biodiversity since many endangered species live in China's forests. Trees as carbon sinks might bring in money to support reforestation if China should one day drop its current opposition to green gas emission permit trading proposals. In Malaysia, the Forest Research Institute of Malaysia (FRIM) is renowned for its expertise in sustainable forestry management. Malaysian timber is recognized as one of the few that is produced sustainably by the World Timber Council. The Malaysian Government has also taken forest and wetlands conservation further by gazetting them as national or state parks, as well as wildlife sanctuary, water catchments, geological wonders, ecotourism spots, and other status. Likewise, such a practice of reforestation is also carried out by the USA.

Major lessons can be drawn from the severe floods of recent decades in China, the USA and Malaysia. As a developed country, the USA have the necessary funds to ensure that reforestation of forests and restoration of wetlands proceed smoothly. However, this may not be the case in developing countries like China and Malaysia who depend on forestry and farming. These two countries must find the right balance between conservation and exploitation. Any conservation and reforestation campaign must take into consideration economic as well as social and national interests. Above all, the success of such campaigns may depend upon how the economies of these countries perform now and in the near future. During boom times, when government do not need the money, logging can be scaled back. However, during recession and bad times (which may be used as an excuse), it is likely that logging will be intensified to earn the much needed foreign exchange. Yet, the bottom line is, the damage from a large flood often overshadows whatever amount that can be earned form cutting forests and wetlands. Worse of all, many people lose their lives during a flood and no amount of money can be put on a human life. Hence, no matter how one looks at the issue, floods must be managed well. Whether it be reforestation or forest conservation, employment of structural measures or non-structural measures, or even the use of traditional mechanisms, the authorities have to make a wise choice. Flood loss lessons should be learnt and remembered so that successive governments take floods seriously as an issue of national importance. Government should also educate the people in order to increase public awareness, public co-operation and support for flood protection projects and other related campaigns such as tree planting, restoration of wetlands, river campaigns, and environmental protection.

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Table 1: Significant flood disasters in the Asia-Pacific Region 1990-2000

Year	Country, region	Total losses (US$ millions)	Insured losses (US$ millions)	Deaths
1991	China	15,000	410	3,074
1993	USA	16,000	1,000	45
1993	China	11,000	< 1	3,300
1995	USA	1,800	470	11
1995	North Korea	15,000	< 1	68
1996	China	24,000	445	3,048
1997	Europe	5,900	785	110
1998	China	30,000	NA	3,656
2000	Philippines	4.1	NA	40

* 19,000 ha of rice crop destroyed, 630,000 people homeless (Sources: Munich, 1999; Alexander, 1993 and newspapers).