INTEGRATED WATER RESOURCES MANAGEMENT IN THE MEKONG DELTA VIET NAM

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1. Background Information

The Mekong River is one of the largest river systems in the world, spanning six countries and covering some 4,200 km. The River originates in the Tay Tang Mountains of Tibet and ends in the Ca Mau Peninsula of Vietnam, with a total catchment area of 795,000 km². Across its extent the catchment varies dramatically including a vast array of regional ecosystems, including; alpine plateaus, tropical forests, mountainous highlands, mangroves, coastal wetlands, floodplain forest and arid grasslands. It is home to some 60 million people, 100 different ethnic groups, a key region for the economies of Thailand, Vietnam, Laos and Cambodia, as well as being a rich and important site of biodiversity in Southeast Asia.

The Mekong Delta forms as the river meets the South China Sea, it comprises 5.5 million ha, and is generally denoted as the area downstream of Phnom Penh. Approximately 2.6 million ha lies within the Kingdom of Cambodia, and 3.9 million ha in Vietnam. In general, the low-relief of the deltaic regions has proven more suitable for agriculture and human habitation, consequently the Mekong Delta is the most developed region of the MRB supporting the greatest population densities. Ground levels range between 0.7-1.2 m above sea level, except in the vicinity of the Cambodian border where elevations are approximately 2.0 – 4.0 m including some small mountains in An Giang province.

The focus of this paper is on the part of the Mekong Delta within Vietnam (known as the Cuu Long Delta). The Cuu Long Delta is the southern most extent of the Mekong River Basin, formed over millennia as the river and its tributaries widen, slow down and deposit sediments in response to the low lying elevation of the coastal areas. The CLD comprises 13 provinces, 12% of Vietnam’s national land area and approximately 18 million inhabitants. Largely due to efforts in water management, the CLD has become the ‘rice bowl’ of Vietnam because of its unparalleled productivity for
the country. The CLD contributes 50% of the nation’s food production, including, 95% of rice exports, 65% of fisheries production and 70% of fruit.

**The Lower Mekong Basin**
*A Perspective View from Southwest*

![Figure 1: The Lower Mekong Basin](image)

1.1 **Hydrology**

The Mekong River basin is divided into two sections; the Upper Basin includes the river reach upstream from Yunnan, China, while the Lower Mekong River Basin (LMRB) extends south from Yunnan to the South China Sea. This distinction mirrors changes in the river’s flow, in the Upper Basin, topography is generally steep resulting in narrow catchments, fast flows and high rates of erosion and sediment aggradation. However, in the LMB the river slows, widens and is joined by a large number of tributaries draining the mountainous areas of Laos, and the plains of Thailand, Cambodia and Vietnam. Consequently, the Upper basin only constitutes 24% of the total catchment area, contributes ~16% of the river’s flow but up to 50% of the rivers sediment load.

Kratie is located 315 km north of the Vietnamese-Cambodian border on the mainstream. Flows at this gauging station can be considered representative of the total flows for the Mekong River, as the contribution from the downstream floodplains are small in comparison. Based on data collected at Kratie between 1960 and 2004, the mean monthly discharge of the Mekong River during the wet season is approximately...
23,000 m$^3$/s, while the dry season mean monthly discharge is just 3,200 m$^3$/s. Figure 2 represents the mean monthly discharge data for seven stations along the Mekong River. It can be seen that the majority (~70%) of annual flow is generated downstream from Vientiane (Table 1). It should be noted that while discharges at Kratie are representative of the CLD, other hydrological properties differ greatly. For instance, water depths can reach up to 10m at Kratie, while at Tan Chau and Chau Doc (two stations in the CLD) water depths remain below 4.0 m. Furthermore fluctuations in inundation depths in the CLD are 507cm/day (10-12 cm/day if subject to a big or early flood). This is approximately 1/6-1/4 of the rate of fluctuation in the upstream reaches.

![Figure 2: Mean Monthly Discharge on Mekong Mainstream: 1960-2004 (MRC, 2005)](image)

The complex network of tributaries in the LMB can also be differentiated into two groups based on hydrological function. Tributaries from the north and east drain the high rainfall mountainous regions of Laos in the wet season, while contributions from northeastern Thailand drain low lying areas with high evaporation rates.

Water movement, as it enters the Mekong Delta, is driven by water levels rather than flow volumes. This is exemplified by the Great Tonle Sap Lake. The lake is a crucial part of the regional hydrology and a massive freshwater system (maximum volume ~ 80 billion m$^3$) which became linked to the Mekong River system by the Tonle Sap River some 6,000 years ago. During the wet season the lake receives water from the Mekong River and its surface area expands from 2,500 km$^2$ up to 13,000 km$^2$ flooding the fringing areas and sustaining one of the richest areas of biodiversity in the region, as well as a large portion of Cambodia’s agricultural and fisheries activity. Indeed, more than 75% of the protein consumption of the Cambodian people is supplied
by this system. However, as the dry season approaches, water levels in the lake remain elevated above those in the Mekong River, causing a reversal in flow direction of the Tonle Sap River. In this way, the lake acts as a natural flood water regulator for the downstream deltaic environments, storing water during the wet season and releasing it during the dry season, providing water for irrigation in the Mekong Delta and inhibiting dry season saline intrusion in the CLD.

Table 1: LMB Mainstream Annual Flows (1960-2004) (MRC, 2005)

<table>
<thead>
<tr>
<th>Mainstream Site</th>
<th>Catchment Area (Km$^2$)</th>
<th>Mean Annual Flow</th>
<th>Runoff (mm)</th>
<th>% Total Mekong</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiang Sen</td>
<td>189,000</td>
<td>2,700</td>
<td>85</td>
<td>405</td>
</tr>
<tr>
<td>Luan Prabang</td>
<td>268,000</td>
<td>3,900</td>
<td>123</td>
<td>460</td>
</tr>
<tr>
<td>Chiang Khan</td>
<td>292,000</td>
<td>4,200</td>
<td>133</td>
<td>460</td>
</tr>
<tr>
<td>Vientiane</td>
<td>299,000</td>
<td>4,400</td>
<td>139</td>
<td>460</td>
</tr>
<tr>
<td>Nongkhai</td>
<td>302,000</td>
<td>4,500</td>
<td>142</td>
<td>470</td>
</tr>
<tr>
<td>Nakhon Phanom</td>
<td>373,000</td>
<td>7,100</td>
<td>224</td>
<td>600</td>
</tr>
<tr>
<td>Mukdahan</td>
<td>391,000</td>
<td>7,600</td>
<td>240</td>
<td>610</td>
</tr>
<tr>
<td>Pakse</td>
<td>545,000</td>
<td>9,700</td>
<td>306</td>
<td>560</td>
</tr>
<tr>
<td>Strung Treng</td>
<td>635,000</td>
<td>13,100</td>
<td>413</td>
<td>650</td>
</tr>
<tr>
<td>Kratie</td>
<td>646,000</td>
<td>13,200</td>
<td>416</td>
<td>640</td>
</tr>
<tr>
<td>BASIN TOTAL</td>
<td>760,000</td>
<td>14,500</td>
<td>457</td>
<td>600</td>
</tr>
</tbody>
</table>

Downstream of Phnom Penh, the Mekong River splits into the Tien (Mekong) and Hau (Bassac) rivers. On average, the Tien river receives 83% of the flow annually, while the Bassac receives the remaining 17% (based on measurements at Tan Chau and Chau Doc).

After Vam Nao, flow distributions evens out between the two major reaches with the Tien receiving 51%. This is partly because the Tien River always remains elevated above the Hau River, resulting in the transfer of large volumes of water via the Vam Nao River and constructed canals, evening out the Mekong flow distribution, and creating one of the most important agricultural regions of the CLD between the two river branches.

Flooding in the CLD occurs in the wet season and generally manifests two peaks. The leading peak occurs in late August, followed by the main peak in September/October. The main peak is the superstition of seasonal monsoon activity and the advent of storm events from the South China Sea. On average there is one big flood in the CLD once every 5-7 years, based on current history of observation. Flood levels are highest in the northern regions of the CLD (Long Xuyen, Plain of Reeds etc), and are controlled and distributed by an extensive network of canals, sluices and embankments, some of which are more than 300 years old.
1.2 Climate

The Cuu Long Delta (CLD) has two distinct seasons; the dry season is from December to April (winter monsoon and east/northeasterly winds), while the rainy season is from May to November (summer monsoon and west/southwesterly winds). The Southwest Monsoon is the dominant metrological factor responsible for the majority of rainfall, however tropical cyclones in the latter part of the wet season make August – October the wettest months of the year as they compound normal monsoonal rainfall. The Upper Basin is also driven by monsoons, however the climate varies significantly from temperate to subtropical.

Rainfall in the CLD averages 1,200-2,400mm, with more than 90% falling in the wet season. Temperatures remain constant throughout the year, ranging from 26-27°degC, with little variation across the entire CLD.

1.3 Landuse

Table 2: Key characteristics of MRB landforms

<table>
<thead>
<tr>
<th>Landforms</th>
<th>Rainfall (mm/year)</th>
<th>Vegetation</th>
<th>Population density pers/km²</th>
<th>Chief Economic activities</th>
<th>Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lancang River Basin</td>
<td>Variable</td>
<td>Mountain brush, meadow, pine forest, mixed evergreen and broad leaved, arable land</td>
<td>Low to moderate: 7-145</td>
<td>Agriculture, (frequently shifting)</td>
<td>Erosion, forest degradation, natural disasters</td>
</tr>
<tr>
<td>Northern Highlands</td>
<td>Wet: 2,000-2,800</td>
<td>Grassland, hill evergreen and mountain forest</td>
<td>Low: 8-15</td>
<td>Agriculture (frequently shifting)</td>
<td>Erosion, forest degradation</td>
</tr>
<tr>
<td>Korat and Sakon plateau</td>
<td>Relatively dry: 1,000-1,600</td>
<td>Scrub, grass land, arable land</td>
<td>Moderate: 80-160</td>
<td>Agriculture, (irrigated and rainfed)</td>
<td>Limited water resources, floods and drought, salinization, rather low fertility</td>
</tr>
<tr>
<td>Eastern Highlands</td>
<td>Wet: 2,000-3,2000</td>
<td>Up land savannah, rainforest</td>
<td>Low: 6-33</td>
<td>Agriculture (Shifting)</td>
<td>Erosion, soil degradation, forest degradation</td>
</tr>
<tr>
<td>Low land</td>
<td>Variable: 1,100-2,400</td>
<td>Arable land</td>
<td>Moderate to dense: 10-570</td>
<td>Agriculture (rice cultivation)</td>
<td>Flooding, Acid sulfate soil, salinity intrusion, drought</td>
</tr>
<tr>
<td>Southern Upland</td>
<td>Relatively wet: 1,600</td>
<td>Dense forest</td>
<td>Less than: 8</td>
<td>Some shifting agriculture</td>
<td>Vulnerable environment natural reserve</td>
</tr>
</tbody>
</table>
Water and biodiversity are the most abundant resources in the LMRB, consequently the dominant landuses are forest cover and agricultural activity (rice and vegetable farming), with a significant amount of aquaculture (shrimp and fish farming) especially in the Mekong Delta.

Loss of forest cover has been one of the most significant factors affecting the Mekong River Basin in the past 50 years. Slash and burn farming techniques alone, account for the loss of 175,000 km\(^2\) by 1985. In Thailand, forest covered 42% of the Korat Plateau in 1961, this figure dropped to just 13% by 1993. In Cambodia, forest cover dropped from 73% (1973) to 63% (1993), with deforestation accelerating during the period 1989-1992. The CLD forests have been the most severely affected, remnant forests cover only 10% of the CLD. According to FAO, forest cover in the LMRB now accounts for no more than 27% of the basin area. Thailand has one of the fastest rates of deforestation (~320,000 ha/yr), while Laos PDR, one of the more underdeveloped member states and most heavily forested, loses 125,000 ha/yr.

For human communities in the LMRB, the floodplain is the fundamental ecosystem component, supporting; surface water sources (eg small lakes, canals), the majority of agricultural and aquacultural land, and remnants of flooded forests. Floodplains are typically bounded by transport works and highways elevated above floodwaters in order to connect human settlements. Natural ground elevations vary little (from 0.3-2.0 m) making flooding the dominant hydrological feature of the CLD.

1.4 Water Resource Issues in the Mekong Delta

From 1990 – 1994, with sponsorship from UNDP, the Netherlands Engineering Consultants (NEDECO) and national experts developed a Master Plan for the Mekong Delta. The Master Plan pointed out that socio-economic development in the Mekong Delta mainly relied upon land and water natural resources contributing to increase agricultural production, especially for rice. However, the Master Plan did not fully investigate the development of industry and other services in the Mekong Delta. The Master Plan has identified the following problems as the major land and water problems facing the Mekong Delta:

1. Acute flooding in the wet season;
2. Acid sulphate soils, and their effects on soil productivity, drainage water quality and aquatic productivity;
3. Dry season saline intrusion;
4. Adverse impacts of salt intrusion sluices on land/water production and acidification;
5. Depletion of coastal mangroves and protected areas for fish breeding;
To this list, increased sediment loads and fresh water shortages could also be added. However, of these issues, land and water contamination is considered to be the most significant, driven by the twin issues of; salinity intrusion and acid-sulphate soil generation. On both a national and an international level, a large amount of effort has been invested in controlling salinity and soil/water acidification to protect the livelihoods and remnant ecosystems of the Mekong Delta.

Furthermore, the Mekong Delta is highly sensitive to the impact from current natural disasters, which is likely to become more pronounced in the future under a warming climate.

**Acute Flooding in the Wet Season**

The mean annual discharge of the Mekong River is approximately 475,000 km³, with the highland areas of Laos contributing more than half of the total. In the Mekong Delta flood water levels range between 0.5-4.0 m and can affect 1.2-19 million ha. Without water resource management (WRM) initiatives inundation can last for 3-5 months. Recent high floods have occurred in 2002, 2001, 2000 and 1996.

However, it should be noted that flooding is a natural feature of the Mekong River, and floods have both positive and negative impacts on riparian communities. In fact, people living in the Mekong Delta do not consider floods as disasters. It is a disaster when there is no flood, early floods or extreme flooding. Indeed one of MRC’s philosophies is ‘living with floods’, recognizing the importance of the Mekong River’s unique flood regime to the livelihoods and biodiversity of the delta region.

**Dry Season Freshwater Shortages**

Minimum flows in the dry season display some seasonal variability, however in general flow in the Mekong River drops to approximately 2,000 m³/s at Tan Chau station in Chau Doc (see figure). Consequently, 2.0 million ha of land is affected by these shortages during the low flow seasons. Most of this occurs in the saline and acid sulphate soils of the coastal belt, in particular for the Ca Mau peninsula.

**Dry Season Saline Intrusion**

Dry season water shortages (see above) in coastal areas, coupled with the two tidal regimes of the South China Sea and the Gulf of Thailand regulate the intrusion of saline waters into the delta. Saline intrusion is a key geophysical process for mangrove ecosystems and an important determinant in the balance between agriculture and aquaculture.

Saline intrusion is most prominent in the coastal provinces of Ca Mau, Bac Lieu and Soc Trang. Salinity levels of up to 4g/L can penetrate 40-50 km inland and last
from 1-3 months annually. Saline intrusion was strongest in the years 1998, 1993, 1977 and can be managed effectively for a large portion of the coastal belt using sluices, sea dykes and mangroves.

*Acid Sulphate Soils*

Acid sulphate soils (ASS) occur in 1.4-1.6 million ha, with approximately 57% of these areas classified as ‘problem soils’. The ‘Plain of Reeds’, ‘Long Xuyen Quadrangle’ and Ca Mau Peninsula are some of the worst affected.

ASS soils contain pyrite, which oxidizes in the presence of air to liberate acid from the soils and convert the pyrite to jarosite. The problem occurs mainly during the first flushes of the wet season, when run-off leaches acidity from the soil and flows overland and through the canals to the coast. During this time, crops and other farming activity can be damaged and even ruined by the drop in pH.

Based on the studies conducted in the Mekong Delta, the Mekong Delta can be divided into 3 hydraulic zones:

- **Flooded Zone:** mainly affected by inundation, consisting of the northern Mekong Delta including parts of An Giang and Dong Thap and province;
- **Mixed Zone:** affected by both floods and tidal action (Cai Lon River, Xeo Chit creek, Lai Hieu canal, Mang Thit river, Ben Tre river and Cho Gao canal.
- **Tidal Zone:** mainly affected by saline intrusion, consisting of a coastal belt up to 40-50 km thick, especially on the South China Sea coastline.

2. **What is Integrated Water Resources Management**

Our Southern Institute for Water Resources Planning (SIWRP) as the main counterpart or the leading agency to assist the Ministries concerned in developing the Master Plan and Strategy & Action Plan regarding water resources in the south of Viet Nam. Water resources serve many ecosystem, agricultural and socio-economic functions in the LMRB, however it has become clear to scientists and planners alike, that these functions are inter-dependent. Integrated water resources management (IWRM) is a systematic and holistic management approach based on understanding the links between these, often competing, functions. By linking land and water development, water extraction and control, use and supply systems can be optimized to ensure the sustainable and equitable distribution of benefits to all stakeholders in the LMRB. Furthermore, IWRM should not only focus on developing water resources, but should manage water development in order to guarantee the long term sustainability and availability of these resources for future generations.
In order for IWRM to be effective it must cover the entire river basin. This is because the catchment is the smallest complete hydrological unit, so that most hydrological functions are contained within the catchment boundary. The use of smaller geographical units can be important for local issues, however, planning that is not directed from the catchment level runs the risk of mismanaging key issues. This implies that multinational cooperation is needed between all states, which the Mekong flows through. To date there has been good cooperation between Thailand, Laos, Cambodia and Vietnam, especially through the MRC and bilateral agreements. China
and Myanmar, the two non-MRC states, have been less willing to participate in coordinating activities. Although in 1996 both China and Myanmar became Dialogue Partners of the MRC, and it is hoped that in the future, especially as hydropower becomes increasingly prevalent in the MRB, that China will cooperate with downstream countries for the benefit of all nations.

IWRM improves security and efficiency of water supply and sanitation services, productivity and planting strategies in the agricultural sector and ascribes value to ecosystem functions for suitable management. There is a growing and successful history of IWRM amongst the member states of the MRC.

International organizations like the MRC, national and provincial authorities together with NGOs have a history of using IWRM to address the issues mentioned in the previous section. The following is a summary of these initiatives.

Figure 4: Water Resources Development Strategy for the Mekong Delta

2.1 Purpose Of Flood Control Initiatives

The fundamental purpose of controlling floods is to protect the lives and livelihoods of communities in the Mekong Delta. Secondary concerns include
protecting infrastructure and built environments. Planning in the Mekong Delta divides flooding into two categories; shallow and deep floods.

Shallow flood areas are typically flooded to depths of 0.2 m. The primary management objectives in shallow flood areas are to actively prevent and drain elevated flood waters, by diverting and controlling floodwaters. This can reduce the duration of extreme water levels, protect lives and infrastructure as well as crops and livelihoods. Plans are being completed for comprehensive hydraulic works to prevent flooding while considering other water resource issues.

In deep flood areas (water levels of up to 4.0 m), WRM aims to:

- Control flood timing by minimizing the impact of early (August) and late floods (November/December), in order to secure agricultural production;
- Reduce loss of life and damage to property;
- Promote stable socio-economic development and environmental conservation as a means to improve the livelihoods.
- Continue to build national roads above the 1961 flood level, the 2000 flood has provided a second benchmark for design criteria of the national highways. Lesser roads because they are of lower significance have been built lower, resulting in their periodic flooding;
- Build towns, inhabited centers, schools and infirmaries to withstand design floods.

Additionally, crop planting times have evolved to make best use of flooding. In some areas (Long Xuyen Quadrangle, Plain of Reeds) these measures have been so effective that up to three crops cycles (~100 days each) can be completed each year.

2.2 Flood Control Initiatives

A number of different methods are available for flood planning and control. These methods can be grouped into three broad areas, namely: Structural Methods, Non-Structural Methods and Investigative Works. In the Mekong Delta, the appropriate method, or combination of methods, is determined based on a knowledge of the nature, history and geography of the regional flood regime.

*Structural Methods*

Some of the most common structural methods utilized in the Mekong Delta include:

- **Dams**: form a barrier across flowing water that obstructs, directs or slows down the flow, often creating a reservoir, lake or impoundment. Whilst these structures
have high capital costs and are often associated with negative social and environmental implications, they are quite effective in mitigating floods. A cheaper and more environmentally friendly alternative to conventional dams are rubber dams, which comprise a rubber bag resting upon a concrete floor on a river bed. The bag is then inflated with either water or air to create a barrier. Such structures are to be utilised at Tra Su and Tha La in the Long Xuyen Quadrangular Region.

- **Overflow Spillways**, often located on lower reaches of rivers to divert floodwaters. The river is widened at certain points and allowed to overflow, thereby reducing stress on the main river channel.

- **Dike Systems**: artificial earthen walls built along the edge of a body of water to mitigate floodwaters. They are used extensively and are positioned either upstream (to control floodwaters and reduce their impact on downstream areas) or close to the ocean to reduce tidal influence on flood events. For example, there is a dike line located just south of the Vinh Te canal near the Viet Nam – Cambodia border in the Long Xuyen Quadrangular Region, forming a deep inundation area and protecting downstream areas from excessive overland flow. Also in the same region, a dike system has been implemented near the coastline of the Gulf of Thailand to prevent high tide waters from raising upstream river levels, which would compound flood effects. A similar system is to be utilized in the Southern Nguyen Van Tiep canal area in the Plain of Reeds. Because of the importance of rice production, priority is given to building embankments in the lowest areas, in order to retain the early flood and secure the second rice crop. There is also great pressure from farmers in these low lands to build fully protected areas to enable production of a third annual crop during the flooding period.

- **Canals**: artificial channels that can be used to divert floodwaters, thereby acting as flood ways. Canals are widespread and help divert overland flow through controlled areas. In the Plain of Reeds, there are plans to enlarge the canal system discharging floodwaters to the Tien River, and also the Bo Bo and T Canals between the 2 Vaico Rivers. Closer to the coastline in the Plain of Reeds, there are also plans to enlarge 21 main vertical canals in the Southern Nguyen Van Tiep area, which would help distribute floodwaters to the ocean, limiting overland flow. Similarly in the Long Xuyen Quadrangular area of the Mekong Delta, there are plans to enlarge 18 main canals for draining floodwaters to the West Sea. At the West Sea coastline, there are also plans to dig 20 canals to assist in floodwater discharge.
• **Sluice Control:** a water channel that is controlled at its head by a gate. Operation of these gates can help control the level of floodwaters and tidal influence. For example, sluices are operated in coastal areas of the Mekong Delta to help prevent salinity intrusion, but are also beneficial for controlling the high tide component of floods. Flood protection sluices are also positioned in upstream areas of the Mekong Delta, for example along the Bassac River and Vinh Te Canal near the Viet Nam – Cambodia border.

• **Road Strengthening:** The major flood event in 2000 provided the initiative for reinforcement of the road network. The national roads are being raised to cope with water levels equal to those experienced in the 2000 flood. Rural roads still suffer flooding but improvements to the weakest sections are being carried out. The road network also constitutes an embankment network protecting the low lands against flood.

*Non-Structural*

The following are some non-structural methods for controlling floods:

• **Building and Development Controls (Flood Proofing):** highly beneficial activity, aimed at minimising property damage due to floods. In the Mekong Delta, houses located in high risk areas are being identified in conjunction with vulnerability assessments at the provincial level. Some new settlement clusters have been built for vulnerable families and some are still in progress or planned. Families living in risk areas are being encouraged and supported to move to safer places. Major buildings like schools and hospitals are being built to serve as safe points for the community to congregate when faced with extreme weather.

• **Shifting and Changing crop pattern and schedule.** Land use planning can significantly improve flood control for agricultural activity. Because of the importance of rice production, priority is given to building embankments in the lowest areas, in order to retain the early flood and secure the second rice crop. There is also great pressure from farmers in these low lands to build fully protected areas to enable production of a third annual crop during the flooding period. Such activities can significantly alter flood patterns and should be managed carefully. There is also a highly dynamic balance between agricultural and aquacultural rice production governed by fluctuations in the national and global markets for rice and shrimp. Therefore, the structural control measures (especially sluices and coastal embankments) need to be flexible enough to adapt to changes in farming direction.
- **Education and Awareness Programmes:** consult local residents and authorities on the nature of flooding and flood control measures. This includes transfer of information on important structural flood control measures, such as sluice gate operation, advice on land use patterns, such as crop schedules and embankment construction, and integrating feedback from local communities about the effectiveness of measures. It is important to recognise any education programme as a two-way process, since local residents often have valuable information and ideas to help improve flood control.

- **Emergency Relief:** the Mekong Delta is considered a high risk area for extreme weather conditions, a situation which, according to the IPCC, is likely to worsen due to climate change. It is therefore important that emergency response strategies are in place for such situations. In the Mekong Delta, some efforts have been made to establish evacuation plans, however provinces like Ca Mau with isolated populations and poor transport services require further efforts.

*Investigative Works*

Detailed investigative works are a critical aspect of any comprehensive flood management process. The following activities are commonly used in the Mekong Delta:

- **Numerical Modelling:** Hydrological and hydraulic models are used to simulate flood events on a large scale, set design criteria and predict the influence of hydrological events. Popular models include MIKE-11, VRSAP, SOBEK and RMA2 to name a few. Hydraulic modelling can also be utilised to more accurately simulate flows in channels and through man-made structures.

- **Flood Forecasting and Warning.** The Flood Forecasting and River Monitoring System in the Mekong River Commission (MRC) has improved to provide timely and accurate river forecasts to its member countries in order to reduce the vulnerability of floods in the Lower Mekong Basin. During the dry season (November-May), seven-day river monitoring and low flow forecasts are conducted and updated weekly on the internet while five-day flood forecasts at 21 key stations along the Mekong mainstream during flood season (June-October) are updated on a daily basis. The MRC Forecasting System consists of three main components; data collection and transmission, forecast operation, and forecast dissemination. A variety of forecasting tools are applied for water levels and discharges: The Streamflow Synthesis and Reservoir Regulation model for the upper part of the basin, multiple regression models for the lower reach of the delta with over bank flow, an Artificial Neural Network model for both, upper and lower reaches, and MIKE-11 for flood mapping in Mekong Delta. Forecast
products including water level forecast bulletin are published on the MRC website and disseminated to the National Mekong Committees, concerned line agencies, National Disaster Management Committee and other interested parties by e-mail. This mechanism is important in flood planning, in the short, medium and long term, and methods to improve this are constantly being evaluated.

2.3 Government Initiatives

In addition to irrigation measures, the Government of Vietnam has developed and initiated other measures to specifically protect the livelihoods of the Mekong Delta communities. In recent decades these have included the encouragement of residential clusters, flood proofing of houses, building dykes and boundary embankments, establishing child care centers and providing training in schools of how to remain safe during extreme floods.

3. Impacts and Problems of Water Resource Management

The success of the Mekong Delta as an agricultural and aquacultural area is due to the efforts in IWRM. The Mekong Delta has been instrumental in transforming Vietnam from a net importer of rice to one of the largest global exporters.

3.1 Impacts

IWRM has to a large extent controlled the extremes in water availability, reducing water scarcity in the dry season, while controlling high water levels in the wet season. This has increased productivity as well as increased the security of the Mekong Delta communities and their supporting infrastructure.

More recently, forested and mangrove areas are being recognized as integral components of the Mekong Delta ecosystem, and IWRM has been successful in reducing the devastation from forest fires, as well as protecting forested areas from salinity intrusion.

It should be noted that there have been some adverse effects of WRM. For example, ASS is largely a problem that originated with the proliferation of farming activities. Previously, these soils were covered in a surface layer of peat and organic matter created by the extensive forest cover. As seasonal water levels became more secure in these areas, encouraging farming activity, these forested areas were cleared. Without the continued renewal by the forests the peat layer was quickly eroded away exposing the potentially acid sulphate soils. This was not a problem during the wet season when water cover protected the soil from acidification, but as areas became exposed in the dry season this has become one of the major issues facing WRM in the Mekong Delta. To date, revisions and new efforts in IWRM strategies has meant that only some isolated areas remain extremely affected by ASS.
3.2 Problems

Problems facing IWRM in the Mekong Delta can be divided into four general categories; Technology, institutional, economic and environmental. The following sections summarize the core problems that are being addressed or need to be tackled to improve IWRM in the LMRB.

Technological and knowledge related problems

Related to a planning and development:
- Lack of directed watershed planning for the whole basin.
- Lack of common standard on flood grades for riparian countries
- Short of basic data such as topography, hydrology, plant cover, directive planning on social – economic development for the whole basin.
- No strong hydraulic model accepted by riparian countries.
- Inadequate advanced technologies on integrated management of flood include work and non work solutions.
- The operation schedule for the flood control system in the Mekong Delta is not yet established

Forecasting and warning:
- Lack of medium and long term forecast on flood, so the people in the Mekong Delta have not enough time to deal with flood.
- Insufficiency means, communication - warning equipment on flood.

Dealing with flood
- Local people, particularly children, and the elderly, have not been trained sufficiently to deal with floods.
- Insufficient safety equipment
- Short of reserved material for flooding prevention
- Insufficient medicines and chemicals for solving issues after flood.

Policy, governance and institutional problems
- Further work is required on the coherence of legal and policy frameworks, administrative boundaries and unclear responsibilities for flood management at provincial and local level;
- Inadequate research & extension capacity, etc.

Financial & economic problems
- Absence / insufficiency of economic incentives for farmer and peoples to adopt mitigation measures;
- Poor rural credit for financing flood mitigation measures, etc.

Environmental and social problems
- Absence of environmental management plans, pollution controls, and flood risk insurances.

4. Hydropower Projects

In an age when scientists are beginning to quantify the effects and predict the risks of global warming and climate change, energy production is seen as the sector which can reduce atmospheric CO\textsubscript{2} levels. Consequently, renewable energies and non-emitting methods of power production have been hailed as one of the best methods for humans to temper their effects on the environments. Hydropower is the generation of electricity by converting stored potential energy of water into kinetic energy. It is seen as one of the most realistic alternatives to burning fossil fuels, because of its capabilities to produce large amounts of power, comparable to conventional coal power plants. While hydropower can have adverse effects during the construction phase (air/water pollution, waste disposal, erosion and vegetation destruction), the major impacts arise from the construction and operation of the large dams used in power generation. These include flooding of the dam site and surrounds and alteration to the downstream flow regime.

There are no hydroelectric projects planned in the Mekong Delta, however, the effects of hydrodams extend downstream from the dam site to the ocean outlet. Therefore, as the furtherest downstream extent of the MRB, the Mekong Delta is likely to experience effects (to varying degrees) from all upstream changes to the flow regime.

Although construction of the first Chinese dam began in 1986, very limited data and information on the hydropower dams, including potential impacts on hydrology and the environment are available outside of China. According to the Chinese authorities: “... the Mekong dams will benefit downstream countries, by storing water in the rainy season to reduce flooding and releasing it when needed to increase flow in the dry season”. However, other experts, environmentalists, activists, non-profit organizations, and downstream countries in the Lower Mekong Basin are concerned that China’s Upper Mekong dams will also have negative impacts. The downstream impacts of large hydropower dams depends mainly on their operation regime, storage volume, buffer capacity and release schedule. There is the potential that dam release regimes may improve dry season water availability in some downstream areas, which could be beneficial for agricultural production, however it remains unlikely that such changes to the flow regime and the river’s connectivity will not have adverse effects on the aquatic biota of the river system, especially fish migratory patterns.

In order to store energy, hydroelectric plants must build large dams. During the rainy season they store as much water as possible in order to increase power generation capabilities, however, this significantly reduces downstream flows affecting flooding
and farming activities. It should be noted that to date, there has been no observable change in the downstream flow volumes from the existing Chinese hydropower dams. However, the problem is only likely to get worse as China intends to build a total of 8 hydropower dams on the Mekong mainstream, ranging in capacity from 750MW/120million m$^3$ (Gonguoqiao) to 5,500MW/12,400 million m$^3$ (Nuozhadu).

Downstream effects are exacerbated by extremes in seasonal weather. During particularly dry years, dams can put further strain on water availability in downstream communities. Conversely, in exceptionally wet years dam capacity can be threatened resulting in either controlled or accidental discharges, which can be disastrous to downstream communities.

Hydropower dams will reduce sediment transport to the lower Mekong Delta, currently Chinese erosional processes are responsible for approximately 150-170 million tons of sediment annually. Sediment transport and deposition not only contributes to soil fertility, it is also one of the key geophysical process responsible for the creation and regeneration of the Mekong Delta. At present the Ca Mau peninsula reclaims tens of meters of mangrove land from the sea each year, research is required to assess the predicted effects of the hydropower dams on this and other important processes.

Annual fish production of the lower Mekong River is about 400,000 tons, supplying 80% protein for Cambodia people. Dams break river connectivity and have an adverse impact on fish migration, an integral component of fish breeding cycles. Consequently, fish production and diversity in the LMRB is likely to suffer because of hydropower dams.

Additionally, tourism and the service industry is one of the fastest growing sectors in the LMRB, while the river provides an important transport link, especially for landlocked countries such as Laos. Further research is required into the impact of dams to navigation and tourism.

As Mekong countries continue to develop, their energy needs will also continue to grow. Hydropower is an obvious choice for electricity generation, because of the huge flows in the Mekong River system. However, there are many negative impacts from hydropower, and to date the impacts on downstream communities is not fully understood, nor appropriately quantified. A better understanding of the effects of hydropower on the water quality, ecological functions and other economic sectors of the LMRB is required to better integrate hydro-electricity into IWRM.
5. National Science and Technology Program on Natural Disaster Prevention, Environmental Protection and Rational Utilisation of Natural Resources (KC08/06-10)

Our Southern Institute for Water Resources Planning has the mandates of basin-wide integrated water resources planning and management in the south of Viet Nam; comprehensive and synchronised solutions for disaster mitigation, water supply projects, riverside and seashore training, environment conservation, environmental impact assessment, small scale hydro-power plant development; excusion of international cooperation tasks in regards to water resources, water environment and water quality in accordance with regulations of Ministry of Agriculture and Rural Development (MARD) and the Government.

Our Institute have responsible to study on flood control in the Mekong Delta under the supervision of the Ministry of Science and Technology in Vietnam called the “National Science and Technology Program on Natural Disaster Prevention, Environmental Protection and Rational Utilisation of Natural Resources” Code KC08/06-10.

5.1 Objectives:
- Researching, managing to apply advanced technologies and methods to improve the quality (accuracy, time) of forecasts and warning of some dangerous natural disasters that occur frequently; working out solutions to preventing and mitigating damages caused by these types of natural disasters.
- Clearly identify trends, causes of changes to natural resources, environmental processes at some key areas and proposing solutions to general management, utilization of natural resources and environmental protection.
- Accessing and mastering advanced technologies, creating products and technologies for treating specific domestic environments so as to deal with environmental pollution in some key areas that negatively impacts on human health and natural resources.

5.2 Main Research Contents
- Acquiring, mastering and applying new and modern methods, technologies in identifying the causes (expounding the mechanism, rules of formation) and forecasting the possible impact of some dangerous types of natural disasters that occur frequently in our country, such as storms, backwater due to storms, floods, flash floods, landslides, droughts and other natural disasters.
- Studying the impact of climate change (the ENSO phenomenon) on natural resources and the environment; desertification in some areas of Vietnam; measures to mitigate and reduce their damaging effects.
- Establishing scientific grounds for the general management and planning for effective exploitation, utilization and protection of essential natural resources (water, land, minerals and organisms). Building models for exploiting and general management of natural resources, the environment in specific ecological zones and important river basins.

- Studying the rules of developing and replacing basic ecosystems, diversification, and uniqueness of typical ecosystems; develop solutions and procedures for rehabilitation of the degrading ecosystems in our country.

- Studying adaptation, application and transfer of advanced technologies and managing to create products, technologies suitable for conditions in our country to treat environmental pollution, rational exploitation and utilization of natural resources to serve sustainable socioeconomic development.

- Developing and applying remote sensing techniques, GIS and computational models in researching natural conditions, resources, the environment, and disasters.

5.3 Major Science and Technology Products.

- Summary reports, special subject reports, reference books, published science and technology works, training documents.
- Technology, methods, computational models, software applied in forecast and warning of natural disasters and changes to resources and environment
- Solutions to planning of exploitation, utilization of natural resources and environmental protection.
- Presentation models for environmental protection and utilization of natural resources.
- Technological processes of forecasting environmental processes and treating the environment.
- Atlas, database of natural disasters, environment, and resources.
- Training results, science and technology competence improvement in the area of natural disasters, environment and resources.

6. Conclusions and Future Directions

IWRM is not a product but a process, which promotes the coordinated development and management of water land and related resources. This implies that there is no final solution to water management in the LMRB, as the needs of the community and national targets continue to change, IWRM must be flexible enough to respond to these changes while still managing the impacts to an acceptable level. For example, both fresh and saline water, are good for national production. Farmers have
shown a desire to switch from rice to shrimp farming based on market competition and pricing. This will require WRM planners to create flexible water management solutions which can accommodate the changing desires of the local community, requiring water controls to reflect the stage of development and technical level. Consequently, IWRM also needs to be firmly embedded in national targets and sector objectives.

Riparian countries have successfully utilized hydraulic and hydrological models to determine the optimal operation schedule for a large system, which has been helpful in resolving problems such as the operation of sluices and the management of the fresh-saline water resource distribution in the delta.

Sustainable development of water resources in Mekong delta can only be fully realized through implementation of water resources management policies, strategies and systematic programs together with close cooperation with up-stream countries such as China, Myanmar, Thailand, Laos and Cambodia.

Balance between water users of the Mekong Delta is achievable, though it may require comprise of secondary and tertiary national interests in order to meet key interests of all states. Therefore, if IWRM is to be effective, especially with the increasing threat of risks and hazards in a warming climate, it must involve international cooperation. Riparian countries must work together, while international countries and organisations should offer technical and financial support. This is a critical issue, because Viet Nam is likely to be one of the countries most severely affected by climate change, though it is not one of the countries that has contributed the most to raising CO\textsubscript{2} levels.

Water resources development in such a large international river basin is not without risks and difficulties, however, with close cooperation between all countries of the Mekong Basin and support from donors, the challenges of an economically prosperous, socially just and environmentally sound river basin, for the benefit of all the Mekong people can be overcome.