Need assessment and detailed planning for a harmonious hydrometeorology system for the Sundarbans

Part – II

LOOKING AT COMPARABLE DELTAS :

EXPERIENCES FROM MEKONG

Prelude

Detail discussion on Hydro-meteorological set up in Sundarbans spreading over two countries, namely Bangladesh and India points to the fact that ‘All is Not Well’ with it. There is lack of infrastructure, lack in common understanding, deficiency in technical knowledge, confusion regarding institution, shortage in implementation, lack in trust between two countries and most important lack in sharing of knowledge regarding a delta with same and identical physiographic set up supporting life and livelihood of about 10 million people, although in a miserable state of affair, at the same time internationally accepted as a biodiversity hotspot. Things would have been easier with a common pool of knowledge being shared between authorities of Sundarbans in two countries under the umbrella of any institutionalised form with timely and precise intervention for protection of life and livelihood of these 10 million populations and for conservation of this fragile ecosystem.

Experiences from other deltas where the river is a common thread between adjacent countries producing natural resources and supporting a sizeable number of populations spreading over different countries may help in framing appropriate strategy for building up a common pool of infrastructure and knowledge based on mutual trust and shared benefits between these two neighbouring countries, which are always friendly to each other. The experiences from Mekong River may be counted as the best one since in this case four countries, which are having divergent political set up and even known hostility on several counts, have come together in an institutionalised manner and with several commonly accepted guiding principles for the conservation of natural resources and common gene pool.
which is crucial for life and livelihood of 65 million people living in Lower Mekong Basin (MRC, 2018) in four different countries namely Thailand, Cambodia, Lao PDR and Vietnam, since a sizeable portion of these countries are situated on the same river basin and sharing the water resources of the same river “The Mekong”.

**Introduction**

The Mekong River System originates from the Tibetan Plateau (Tuan, L. A. & et al, 2007) and travels some 4,909 km through six countries namely China, Myanmar, Laos PDR, Thailand, Cambodia and Vietnam and finally discharges into the South China Sea. The Yangtze, Salween, Irrawaddy, Red and Mekong rivers all begin their long journeys on the Tibetan Plateau at 4,500 or more metres above sea level. Here, this family of great rivers are separated by only a few hundred kilometres before moving off in different directions (MRC, 2005). The Yangtze flows across all of central China, the Red River runs through Vietnam to the Gulf of Tonkin, and the Salween and Irrawaddy through Myanmar into the Indian Ocean. The Greater Mekong can be divided into two parts: the Upper Basin in Tibet and China (where the river is called the *Lancang Jiang*), and the Lower Mekong Basin from Yunnan downstream from China to the South China Sea. The Upper Basin makes up 24 per cent of the total area and contributes 15 to 20 per cent of the water that flows into the Mekong River. The catchment here is steep and narrow. Soil erosion has been a major problem and approximately 50 per cent of the sediment in the river comes from the Upper Basin.

From its source, the Mekong continues south for approximately 4,909 km to drain a total land area of 7,95,000 km² which has been designated as Mekong Basin of which 606,000 km² is in the Lower Mekong Basin and comprises almost entire Laos PDR and Cambodia, one third of Thailand (its North-eastern region and part of its Northern region), and one fifth of Vietnam (the Central Highlands and the Delta) (Plate & Insisiengmay, 2002). Interestingly, Mekong Basin, in spite of considerable development and population pressure, has retained the original landscape and the flood inundation to a large extent as a result of which it has protected its rich biological diversity and thereby marked as the 2nd most biologically diverse river in the world (WWF, 2004). The Mekong ranks 10th amongst the world’s great rivers on the basis of mean annual flow at the mouth.
The Mekong River flows are collected from many sources and it has been estimated that annual discharge of Mekong River System is about 470 km$^3$ (Lu and Siew, 2005). Mekong River is extremely important for the economies of these six countries especially Thailand, Laos PDR, Cambodia and Vietnam. It is very much present in the social, economic and cultural life of the four countries of the Lower Mekong Basin (LMB), and shapes the economic prospects of these countries and their mutual relations.

Figure – 1 : Broad Regions of Mekong River Basin (MRC, 2005)

Life and Livelihood of more than 65 million populations spreading over several countries is dependent on the Mekong River and Mekong Basin. The major issues in the basin concern the reasonable and equitable sharing of water resources, and the sustainable development of natural resources (MRC & JICA Report, 2004). The Mekong is the common physical thread that defines the geographical region that is widely referred to as Indochina, drawing together Cambodia, Laos, Thailand and Vietnam into a single international water resources economy. These four countries have long recognised the need for joint cooperation and mutual consideration when planning and designing new water utilisation projects within a single trans-boundary river basin, this spirit of collaboration being embodied in the Mekong Agreement of 1995. Similarly, it has a major impact on the south-western part of PR China, especially Yunnan province. It counts among the 10 largest rivers in the world, but stands apart because of the extreme fluctuations in seasonal discharge: very low flows in the dry
season, yet extensive flooding in the wet season which nurtures the basin’s huge wetlands such as the world famous Tonle Sap in Cambodia (Anonymous, 2006).

Figure – 2 : Topography and Relief of Lower Mekong Basin (MRC, 2005)

According to Mekong News (2003), farmers in the whole Mekong Basin produce enough rice to feed an estimated 300 million people a year. They are producing about half of Vietnam’s
total rice output (Thi Thuy and Furukawa, 2007). Average Sediment discharge by Mekong River is about 160 million tons per year (Milliman & Ren, 1995) (although there is enough variability in figures from different authors), which has similarity with the Ganga–Brahmaputra River system wherein the sediment load has been estimated ranging from 402 to $710 \times 10^6$ tonnes/year for the Brahmaputra River and from 403 to $660 \times 10^6$ tonnes/year for the Ganges River separately and cumulatively 80 to 137 million tons per year (Subramanian & Ramanathan, 1996). Another estimation puts this figure to be around 100 million tons per year (Steven & Steven 1999). Thus, there is distinct similarity in physiographic set up between Ganga Brahmaputra River system giving rise to Ganga Brahmaputra Delta (GBP) on which Sundarban is located and the Mekong River System.

Figure – 3 : Mekong Basin with Political Boundaries of Different Countries (MRC, 2017)
The lower Mekong River, which flows through the Mekong River Delta which is home for 18 million Vietnamese (Tuan et al., 2007), is controlled by tides and seasonal variations of fluvial discharge. The decreased freshwater flow in the lower Mekong channel modifies flow and sediment dynamics, and intensifies saltwater intrusion in the low-flow season (Gagliano and McIntire, 1968). Combining with the subsidence and sea-level rise, the Mekong Delta is predicted to experience significant changes in its future evolution (Ericson et al., 2006; Carew-Reid, 2008; McSweeney et al., 2010; Erban et al., 2014). Thus, there is a great deal of similarity of Sundarbans with Mekong Delta since it also experiences subsidence.

The Mekong River bifurcates into the Song Hau and the Song Tien distributaries in the delta plain. The two distributaries ultimately divide into eight channels which flow into East Sea. The lower Song Hau distributary includes Dinh An and Tran De sub-distributary channels (Xien et al, 2017). The Song Hau distributary carries about 41% of the total Mekong water discharge, of which ~70% flows through the Dinh An channel and ~30% flows through the Tran De channel (Nguyen et al., 2008).

Current estimates of the annual sediment load for the Mekong River vary significantly from 40 to 160 Mt (Walling, 2008: 160 Mt/yr; Milliman and Farnsworth, 2011: 110 Mt/yr; Lu et al., 2014: 50–91 Mt/yr; Nowacki et al., 2015: 40 Mt/yr). Milliman and Farnsworth (2011) estimated that the annual dissolved sediment load is approximately 60 Mt.

The Lower Mekong River Basin Accounts for 76% of the entire basin, as given below:

Table – 1: Distribution of Catchment area of the Mekong River in six different countries

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Country</th>
<th>Catchment Area (km²)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>China</td>
<td>165,000 (21%)</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Mynamar</td>
<td>24,000 (3%)</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Laos PDR</td>
<td>202,000 (25%)</td>
<td>Lower Mekong River Basin’s total</td>
</tr>
<tr>
<td>4.</td>
<td>Thailand</td>
<td>184,000 (23%)</td>
<td>Catchment Area: 606,000 km² (76% of entire basin)</td>
</tr>
<tr>
<td>5.</td>
<td>Cambodia</td>
<td>155,000 (20%)</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Vietnam</td>
<td>65,000 (8%)</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Total</td>
<td>795,000</td>
<td></td>
</tr>
</tbody>
</table>

Source: Joint Report of MRC & JICA, 2004
The Mekong Delta section of the LMB is in Vietnam, the last country through which the Mekong River reaches out into the East Sea. The catchment area of the Mekong River Basin in Vietnam is 65,000 km² (Tuan, L. A. & et al, 2007). Similar to GBD, the river network of Mekong also forms an intricate network of rivers and a dense canal network as it approaches the sea.

The Mekong meets Tonle Sap River west of Phnom Penh. The Mekong then flows across the border of Vietnam especially from the Tonle Sap River in Cambodia to the East Sea of Vietnam. After entering Vietnam, the Mekong River splits into two branches, the Bassac (known as the
Hau River in Vietnam) and the Mekong (known as the Tien River in Vietnam). These two branches actually form the Mekong Delta (Abedin et al, 2013). The Hau River is the southernmost branch of the river system. The Hau River subsequently splits into two sub-branches: Tran De and Dinh An. The Tien River is the northern branch of the Mekong River system, which also separates at a place known as Vinh Long into two sub-branches namely, Co Chien and My Tho. At a distance of 30 km from the South China Sea, the Co Chien River again splits into two smaller branches, Co Chien and Cung Hau. In the downstream part, the My Tho River separates into four branches: Tieu, Dai, Ba Lai, and Ham Luong. Six tributaries of the Tien River and three tributaries of the Hau River together form what is called in the Vietnamese language the “Nine Dragons” (Cuu Long) (Tuan, L. A. & et al, 2007). The River discharge at Tan Chau is 3-5 times larger than that of Chau Doc (Nguyen, 2006). The Vam Nao, connecting river 20 km downstream of Tan Chau and Chau Doc, conveys water from the Tien River to the Hau River, augmenting flow downstream of this point.

Most part of the Mekong Delta is situated within Vietnam itself and is distributed in 13 provinces, namely Long An, Tien Giang, Ben Tre, Dong Thap, Vinh Long, Tra Vinh, An Giang, Can Tho, Hau Giang, Soc Trang, Bac Lieu, Ca Mau, and Kien Giang (Abedin et al, 2013). The Delta covers an area of 39,000 km². Total population living in the Mekong Delta is about 18 million people. Delta’s rich resources are of vital importance to Vietnam, as they account for some 40% of agricultural production in the country, including 50% of the rice production (Trinh & Nguyen, 2005). Rice and fishery products contribute significantly to export earnings and account for about 27% of the gross domestic product (Abedin et al, 2013).

There is an extensive network of canals that has been constructed in the last 300 years. The structures comprise 7,000 km of main canals, 4,000 km of secondary canals on-farm systems, and more than 20,000 km of protection dykes to prevent early floods (MARD, 2003). Thus, such a situation is similar to Sundarbans wherein earthen embankments and polders have been constructed over last 250 years to protect the islands from inundation.

The Mekong delta is a multi-channel estuary where the tide is damped due to a relatively strong river discharge (in the order of 2000 m³/s), even during the dry season. As a result, the tide is strongly damped and the branches of the delta are rather prolonged. This gives the Mekong estuary a clearly riverine character (Nguyen & Savenije 2006). Tidal water-level changes are observed in Cambodia, more than 200 km upstream from the river mouth (Saito et al, 2015).

Flood and salinity intrusion are natural phenomena, not disasters in Mekong Delta. They only become “disasters” when a great number of a valuable property is damaged and the life of
people is endangered. This is due to the increased industrial development and expansion of human settlement in the flood prone area as the delta is one of the most resource rich in Vietnam. An Early Warning System and participatory water management are needed to reduce the disaster risks related to flood in Mekong Delta. A number of scenarios have been considered on two water level measuring stations at Tan Chau (on Tien River) and at Chau Doc (on Hau River) (Tuan, L. A. & et al, 2007).

Table – 2 :  Warning Water Levels (in m) for flood events in the Mekong Delta

<table>
<thead>
<tr>
<th>Levels</th>
<th>Gauging Stations</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tan Chau (Tien River)</td>
<td>Chau Doc (Hau River)</td>
</tr>
<tr>
<td>I.</td>
<td>≤ 3.0</td>
<td>≤ 2.5</td>
</tr>
<tr>
<td></td>
<td>Possible flood condition – River water level is high; threat to low height embankments; flooding of very low lying areas; infrastructure safe.</td>
<td></td>
</tr>
<tr>
<td>II.</td>
<td>≤ 3.6</td>
<td>≤ 3.0</td>
</tr>
<tr>
<td></td>
<td>Dangerous flood condition – Flood plain inundation expected; towns and cities still generally protected by flood defences; high velocity river flows pose danger of bank and dyke erosion; bridge foundations at risk from scour, infrastructure generally safe.</td>
<td></td>
</tr>
<tr>
<td>III.</td>
<td>≤ 4.2</td>
<td>≤ 3.5</td>
</tr>
<tr>
<td></td>
<td>Very dangerous flood condition – All low lying areas submerged, including low lying areas of cities and towns; safety of River protection dykes in jeopardy; damage to infrastructure begins</td>
<td></td>
</tr>
<tr>
<td>Over III</td>
<td>&gt; 4.2</td>
<td>&gt; 3.5</td>
</tr>
<tr>
<td></td>
<td>Emergency flood condition – General and wide spread uncontrollable flooding; dyke failure a certainty and probably uncontrollable; damage to infrastructure severe</td>
<td></td>
</tr>
</tbody>
</table>


In the Mekong Delta, approximately 1 million ha are affected by tidal flooding and 1.7 million ha (about 45% of the delta area) by salt water intrusion (Reiner et al, 2004) from both the East Sea and the Gulf of Thailand to open waterways and estuaries for some period during the year, with much of this land exposed for a duration of over six months.

Mekong delta has prograded more than 200 km over at least the last 6-7 ka. The river-mouth area of the delta is meso-tidal with the mean tidal range of 2.5 ± 0.1 m and the maximum tidal range is 3.2-3.8 m (Y. Saito et al, 2015). The mean wave height is 0.9 m. Its water discharge is 470 km³/y and its sediment discharge is 160 million ton/year, or tenth and ninth largest in the world respectively. The water discharge varies by season because most of the drainage area is under a monsoonal tropical regime. The flow at Phnom Penh, Cambodia, reaches a maximum in October (typically 39,000 m³/s) and a minimum in May (about 1700 m³/s). Tidal water-level changes are observed in Cambodia, more than 200 km upstream from the river.
mouth. The sediment characteristics clearly indicated the tide and river influenced (meaning freshwater section) parts of Mekong River, which are closely linked with river morphology (Y. Saito et al, 2015).

**Tide Gauge Stations in Vietnam including Mekong Delta**

All other five countries through which the Mekong River passes are having coast along the borders. However since Mekong finally meets the South China Sea in Vietnam, that is why tide gauge stations along Vietnam have been specially examined.

The Sea Level Observation in Vietnam started at Hon Due station from the year 1938, although in between time interrupted by the war (MNRE, 2016). Measurement of sea level once again started from January, 1956 and measurement of four times a day started from 1957. Due to several reasons, data from this station is not available between 1945 and March, 1960. From June 1965, elevation of the station changed.

Thereafter, considering the importance of sea level measurements, a number of tide gauge stations also come up in the North Vietnam such as Co To, Bach Long Vy (1958), Cua Ong, Bai Chay (1960), Hon Ngu (1961), Con Co (1974) and Sam Son (1998). Many of these stations like Bach Long Vy, Hon Ngu etc. stopped measuring water level temporarily due to Vietnam war. However, all these stations resumed the service after war. As for example, Hon Ngu Station and Bach Long Vy stations have started functioning since 1990 and 1998 respectively. In most of these stations, water level is measured in hydrostatic equipment and measurement is taken four times a day.

In the south, the Quy Nhon navigational station was established in 1958 and began monitoring in 1959. Due to war, Quy Nhon station stopped its observation from 1965 and thereafter its observation became stable since 1986. Since April 1986, the water level was measured in hours. There was continuous change in techniques of water level measurements also. The water level was measured initially by hydrostatic method, thereafter by Sum machine and finally by Stevens-A35 machine (since 1992). Data from April 1986 is continuous (MNRE, 2016).

After 1975, in South Vietnam, many marine stations were built up such as Vung Tau, Son Tra (1978), Phu Quy (1979), Con Dao (1986), Phu Quoc (1986), DK I-7 (1992), Tho Chu (1993), Truong Sa (2002) etc. The sea level is mainly monitored in these stations by hydrostatic instruments and 4 times a day, although in a few stations tide gauges were also installed. Most stations have relatively stable measurement data. Particularly, the DK I-7 station is located on a floating platform, with sea level data with hourly measurements using the Steven A-71 water level meter since 1992. Thus, by 2014, in Vietnam there are 17 marine
observation stations along the coast and islands. Among them, Truong Sa station has relatively short data series (13 years), DK I-7 station has unstable data due to hydrostatic instrument attached to the floating platform.

Thus, a number of tide gauge stations are there in Vietnam as per the nodal department, although data available from these stations may not be continuous over a long period of time. However, MNRE for making models on climate change depended on following 15 (fifteen) stations, as follows:

Table – 3 : Tide Gauge Stations with reliable data over a long period of time (MNRE, 2016)

<table>
<thead>
<tr>
<th>No</th>
<th>Name of station</th>
<th>Data series</th>
<th>Equipment</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cua Ong</td>
<td>1962-2014</td>
<td>Gauge</td>
<td>Coastal Station</td>
</tr>
<tr>
<td>2</td>
<td>Co To</td>
<td>1960-2014</td>
<td>Gauge</td>
<td>Island</td>
</tr>
<tr>
<td>3</td>
<td>Bai Chay</td>
<td>1962-2014</td>
<td>Gauge</td>
<td>Coastal Station</td>
</tr>
<tr>
<td>4</td>
<td>Bach Long Vi</td>
<td>1998-2014</td>
<td>Gauge</td>
<td>Island</td>
</tr>
<tr>
<td>5</td>
<td>Hon Dau</td>
<td>1960-2014</td>
<td>CYM Machine</td>
<td>Island</td>
</tr>
<tr>
<td>6</td>
<td>Sam Son</td>
<td>1998-2014</td>
<td>Gauge</td>
<td>Coastal Station</td>
</tr>
<tr>
<td>7</td>
<td>Hon Ng</td>
<td>1961-2014</td>
<td>Gauge, CYM Machine</td>
<td>Island</td>
</tr>
<tr>
<td>8</td>
<td>Con Co</td>
<td>1981-2014</td>
<td>Gauge</td>
<td>Island</td>
</tr>
<tr>
<td>9</td>
<td>Son Tra</td>
<td>1978-2014</td>
<td>Gauge</td>
<td>Coastal Station</td>
</tr>
<tr>
<td>10</td>
<td>Quy Nhon</td>
<td>1986-2014</td>
<td>Gauge, Steven Machine</td>
<td>Coastal Station</td>
</tr>
<tr>
<td>11</td>
<td>Phu Quy</td>
<td>1986-2014</td>
<td>Gauge</td>
<td>Island</td>
</tr>
<tr>
<td>12</td>
<td>Truong Sa</td>
<td>2002-2014</td>
<td>Gauge</td>
<td>Island</td>
</tr>
<tr>
<td>13</td>
<td>Vung Tau</td>
<td>1978-2014</td>
<td>Gauge, Water Level Gauge</td>
<td>Coastal Station</td>
</tr>
<tr>
<td>14</td>
<td>Con Dao</td>
<td>1986-2014</td>
<td>Gauge</td>
<td>Island</td>
</tr>
<tr>
<td>15</td>
<td>DK I-7</td>
<td>1992-2014</td>
<td>Steven A-71 Machine</td>
<td>Floating rigs</td>
</tr>
<tr>
<td>16</td>
<td>Tho Chu</td>
<td>1995-2014</td>
<td>Gauge</td>
<td>Island</td>
</tr>
<tr>
<td>17</td>
<td>Phu Quoc</td>
<td>1986-2014</td>
<td>Steven A-71 Machine</td>
<td>Island</td>
</tr>
</tbody>
</table>

In Vietnam, there are altogether seven tide stations, data for which are being maintained at Permanent Service for Mean Sea Level (PSMSL) (http://www.psmsl.org/), the International agency. The Coast Code of Vietnam in PSMSL is 605. PSMSL is the global data bank for long term sea level change information from tide gauges and bottom pressure recorders. Interestingly, although Da Nang is a PSMSL station, the data for this station has not been considered by MNRE. The details of the PSMSL stations are given below:

Table – 4 : Details of PSMSL Tide Gauge Stations in Vietnam

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of the Station</th>
<th>Stn. ID</th>
<th>Station Code</th>
<th>Latitude in DD N</th>
<th>Longitude in DD E</th>
<th>Time Span of Data</th>
<th>Date of Last Update</th>
<th>Type of Gauge</th>
<th>Data Authority</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Station</td>
<td>Code</td>
<td>Year</td>
<td>Latitude</td>
<td>Longitude</td>
<td>Start Year</td>
<td>End Year</td>
<td>Datum Value</td>
<td>Authority</td>
</tr>
<tr>
<td>---</td>
<td>---------</td>
<td>------</td>
<td>------</td>
<td>----------</td>
<td>-----------</td>
<td>------------</td>
<td>----------</td>
<td>-------------</td>
<td>-----------</td>
</tr>
<tr>
<td>2.</td>
<td>Vung Tau II</td>
<td>2268</td>
<td>22</td>
<td>10.34</td>
<td>107.071667</td>
<td>2007 – 2016</td>
<td>28.02.18</td>
<td>Univ. of Hawaii</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Hon Dau</td>
<td>841</td>
<td>81</td>
<td>20.666667</td>
<td>106.8</td>
<td>1957 – 2013</td>
<td>17.11.15</td>
<td>Unknown</td>
<td>HM &amp; ESNC</td>
</tr>
<tr>
<td>4.</td>
<td>Hon Ngu</td>
<td>1003</td>
<td>61</td>
<td>18.8</td>
<td>105.766667</td>
<td>1962 – 2013</td>
<td>17.11.2015</td>
<td>Russian Type</td>
<td>HM &amp; ESNC</td>
</tr>
</tbody>
</table>

There are two data authorities for tide gauge stations in Vietnam for these seven stations. These are: 1) Hydro-meteorological and Environmental Station Network Centre (HM & ESNC), No. 62 Nguyen Chi Thanh Street, Dong Da, Hanoi and 2) University of Hawai, Department of Oceanography Division of Natural Sciences, 1000 Pope Road, Honolulu, Hawaii 96822.

Some details regarding these seven tide gauge stations have been provided in the PSMSL website, as stated below:

1. Vung Tau is now an historic station, last data obtained 2001; Monthly mean sea level data values for Vung Tau from 2001-2013 have been supplied by the Institute of Meteorology, Hydrology and Climate Change (IMHEN) Viet Nam.

2. Vung Tau II is a new station; data has been supplied by UHSLC. Using levelling information from UHSLC, the station has been made RLR. Primary benchmark is RE 5.837m above the datum.

3. In case of Hon Dau station, 1960 data was replaced with dataset of 1957-97 received from authority, Now D9 Gauge, a Russian type is in operation, CYM Hondau is now an
historic station; Monthly mean sea level data values for Hon Dau 2001-2013 have been supplied by the Institute of Meteorology, Hydrology and Climate Change (IMHEN) Vietnam.

4. Monthly mean sea level data values for Hon Ngu 2001-2013 have been supplied by the Institute of Meteorology, Hydrology and Climate Change (IMHEN) Viet Nam. CYM Hon Ngu is a historic station.

5. Qui Nhon II is a new station; Data has been supplied by UHSLC. Using information from the UHSLC levelling sheet, Qui Nhon II has been made RLR. Primary benchmark is KTTV which is 5.166 m above the datum. Complete updated JASL dataset 2007-2014 loaded onto the database.

6. Qui-Nhon 605/041 RLR (1990) is 8.9 m below TGBM; In April 1993, the station moved 500 m from the old spot with a new reference BM; data for 1987-94 revised with data set received for 1977-97 from authority D9. Following receipt of 1977-97 data, the RLR for Qui Nhon was revised and RLR(1997) is 10.8m below BM. Initially there was a MHV 2 type tide gauge. From 1977 to September 1993 a Russian type CYM tide gauge was used and from October 1993 onwards, American type, Stevens A35 tide gauge is being used. The gauge was relocated to another bank of the Qui Nhon Gulf in April 1993; Monthly mean sea level data values for Qui Nhon 2001-2013 have been supplied by the Institute of Meteorology, Hydrology and Climate Change (IMHEN) Viet Nam.

7. In case of Da Nang tide gauge station, a Russian type, CYM was used from 1977 - March 1992 and from April 1992 onwards – American type, Stevens A71 is now being used. Da Nang is now an historic station; Monthly mean sea level data values for Da Nang 2001-2013 have been supplied by the Institute of Meteorology, Hydrology and Climate Change (IMHEN) Viet Nam.

A ‘Float Type’ tide gauge is being used at Qui Nhon Tide station; Digital Recording is now going on. Apart from tide data, it also measures Sea Temperature as an Additional Parameter; Data Recording is continuous. Primary data from period 1959 to 1963 recorded by float gauge/stilling well was lost because of the war and the tide gauge was completely ruined. It is quite accessible since Qui Nhon Railway station is only 3km from gauge; (Source : Website of British Oceanographic Data Centre, https://www.bodc.ac.uk/resources/inventories/gloss_handbook/stations/75/ accessed on 31.08.2018). Qui Nhon and Qui Nhon II are GLOSS Stations with GLOSS ID 75.

Additional Tide Gauges
There are several International agencies apart from PSMSL, who also cater the need of tide gauge data on regular basis in the public domain. Out of many such agencies, two agencies, namely Tide Forecast (https://www.tide-forecast.com/locations) and Mobile Graphics (http://tides.mobilegeographics.com/locations/880.html) are quite known and their services are also quite reliable.

As per the Mobile Graphics (http://tides.mobilegeographics.com/locations/880.html), there are altogether eight tide gauge stations in Vietnam. Out of these eight tide gauge stations, Vung Tau and Da Nong, which appear in the tide gauge list of PSMSL also, are common. Details of other six tide stations, which are also included in the list, are given below:

Table – 5: Details of Tide Gauge Stations as recorded in database of Mobile Graphics

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of the Station</th>
<th>Latitude in DD N</th>
<th>Longitude in DD E</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Cam Pha</td>
<td>21.0333</td>
<td>107.3667</td>
</tr>
<tr>
<td>2.</td>
<td>Cam Ranh</td>
<td>11.8833</td>
<td>109.2000</td>
</tr>
<tr>
<td>3.</td>
<td>Do Son</td>
<td>20.6667</td>
<td>106.8000</td>
</tr>
<tr>
<td>4.</td>
<td>Haiphong</td>
<td>20.8667</td>
<td>106.6667</td>
</tr>
<tr>
<td>5.</td>
<td>Hon Nieu</td>
<td>18.8000</td>
<td>105.7667</td>
</tr>
<tr>
<td>6.</td>
<td>Hon Gay</td>
<td>20.9500</td>
<td>107.0667</td>
</tr>
<tr>
<td>7.</td>
<td>Song Cau</td>
<td>13.5912</td>
<td>109.2497</td>
</tr>
<tr>
<td>8.</td>
<td>Phan Thiet</td>
<td>10.9452</td>
<td>108.2619</td>
</tr>
</tbody>
</table>

Tide at all these places are harmonic in nature. Any person from anywhere in the world can get the tide condition in any station just by clicking on any of these stations in their website.

Similarly, Tide Forecast also maintains a website (https://www.tide-forecast.com/locations) for announcement of the tide conditions of different stations all over the world. In that website, names of altogether nineteen tide stations spreading over the entire Vietnam are there. Anyone can get the tide conditions of any of these stations from the website at any point of time. These tide stations are:

1. Cam Pha
2. Cam Ranh
3. Da Nang
Out of these nineteen stations, first ten stations are already covered by other agencies like PSMSL and Mobile Graphics. Thereby, data for another 9 (nine) stations are available from these web portal along the Vietnam coast. In a combined manner, altogether names of 35 tide gauge stations are available in public domain.

Water discharges are also measured at Tan Chau and Chau Doc stations over Song Hau distributary of Mekong River and rating curves (which establishes relationship between Water Height in cms/mts and the volume of Discharge of water in cubic meters) are generally created here on regular basis. Water Level measurements are the preliminary requirements for creation of ‘Rating Curves’ and thereby there must have some water measurement arrangements for measuring water levels at these two stations used to develop rating curves to correlate water levels to water discharges at Tan Chau and Chau Doc stations (Xing et al, 2017). In the estuary of the Hau River, there are currently two tide monitoring stations, at Dinh An and Can Tho, both of which are operated by Mekong River Commission (MRC) (Takagi et al, 2015)

It is also interesting to note that apart from the above stated number of tide gauges, references of ten ‘tide gauges with more than 20 years’ data have been recorded in literature (Thuc & Son, 2012). There are six tide gauge stations which have not been mentioned by any of the above stated agencies and hence reproduced here:

Table – 6 : Locations of six more tide stations not mentioned earlier

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Station</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.</td>
<td>Do Son</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Dong Hoi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Song Cau</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Quy Nhon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Hon Nieu</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Phan Thiet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Vung Tau</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>Can Gio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.</td>
<td>Duong GJang</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.</td>
<td>Ha Tien</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14.</td>
<td>Haiphang</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.</td>
<td>Hoi An</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.</td>
<td>Hongay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.</td>
<td>Nhatrang</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.</td>
<td>Phan Rang – Thap Cham</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19.</td>
<td>Tuy Hoa</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Tidal action along the Mekong River and its distributaries i.e. the Mekong System is more or less confined within $8^\circ 30' \text{N}$ to $11^\circ 15' \text{N}$ Latitude and $104^\circ 15' \text{E}$ to $107^\circ 50' \text{E}$ Longitude in South Vietnam. So, the tide stations located within this area will serve the purpose for tide measurements along the Mekong System. It seems that Vung Tau, Vung Tau II, are very near to Mekong Delta, about 10 to 15 kilometres north of Mekong Delta while Tan Chau and Chau Doc tide stations can only provide the tide data along the Mekong System.

Interestingly, although MRC is interested in many other parameters regarding Mekong River, Tide Gauge Data along Mekong River, which is one of the most important issues, is somehow not specially mentioned by MRC Secretariat. Although tide plays a very important role in the flow management as well as salinisation of the Mekong Delta, it seems tide data is not being considered important by MRC. This may be due to the fact that MRC is a multi-national conglomerate and tide is effective along Mekong River only up to the border of Cambodia. However, Water Level monitoring for different distributaries of Mekong Delta is being carried out by MRC, as described in subsequent section, which can also easily indicate the tide condition.

From the above discussions, it is obvious that with a coastline of 3260 kilometres, although a number of tide stations are there in Vietnam, the Mekong system does not get much importance so far as tidal action is considered, although Mekong Delta is the backbone of economy and rice bowl of Vietnam.

**Discharge and Sediment Monitoring Programme**

Discharge and Sediment data collection is a core activity of the Mekong River Commission since the Mekong Committee was established in 1957 (Jacobs, 1995). This activity has provided a significant amount of basic data and information for the purpose of project development, design, operation and includes researches and other studies. In addition, the analysis of data will strengthen the understanding of the fluvial geomorphology and climate change processes in the Mekong basin.

<table>
<thead>
<tr>
<th></th>
<th>Co To</th>
<th>21</th>
<th>107.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>Bai Chay</td>
<td>20.9</td>
<td>107.6</td>
</tr>
<tr>
<td>3.</td>
<td>Hon Ngu</td>
<td>18.8</td>
<td>105.8</td>
</tr>
<tr>
<td>4.</td>
<td>Con Co</td>
<td>17.2</td>
<td>107.4</td>
</tr>
<tr>
<td>5.</td>
<td>Son Tra</td>
<td>16.1</td>
<td>108.3</td>
</tr>
<tr>
<td>6.</td>
<td>Phu Quy</td>
<td>10.5</td>
<td>108.9</td>
</tr>
</tbody>
</table>
These programmes are carried out by MRC with the financial support of AFD (Agence Francaise de Developpment – French Development Agency) and the FFEM (French Facility for Global Environment). A number of such programmes are presently run by MRC. As a result of the Mekong agreement, the Discharge and Sediment Monitoring Programme has started since 2009. Objectives of this programme are:

1. Understanding of fluvial geomorphology and climate change
2. Tools and procedures for guiding development of hydro power
3. Capacity Building
4. Project Management
5. Monitoring and evaluation

As per the multi-party agreement and subsequent decisions taken at co-ordination meetings, Information and Knowledge Management Programme of the Sediment Monitoring Project needs to continue the discharge and sediment monitoring activities in mainstream gauging stations from 2009 onward, which is still continuing (Source: http://portal.mrcmekong.org/sediment_monitoring accessed on 31.08.2018).

The data thus collected is used for analyses of fluvial geomorphology and climate change processes in the Mekong basin. It is imperative that in order to make a comprehensive planning for development as also to minimize the damage due to natural calamity, a consequence of climate change, and also for developing an adaptation strategy, these data play an important role. Up-to-

Figure – 5 : Locations of existing and former discharge measurement stations on the lower Mekong River (Source: http://portal.mrcmekong.org/sediment_monitoring accessed on 31.08.18)

date data bank is an essential requirement for making any long term planning.
The main objectives are to collect, compile and provide accurate and reliable water level, discharge and suspended sediment transport data at stations along the Mekong River and Bassac River in the Mekong Basin, as approved by the MRC Joint Committee in 2004, to improve rating curves and to quantify suspended sediment transport at stations in the Mekong region. The project is managed under the Information and Knowledge Management Programme (IKMP) in the Technical Support Division (TSD) of the MRC Secretariat. It is to ensure that all data collected basin wide are securely available in timely manner at the Office of the Secretariat in Phnom Penh (OSP) and the Office of the Secretariat in Vientiane (OSV).

Each country is responsible for the implementing activities of its part of the system with the support and co-ordination of the MRC. The project started in 2010 and made very good progress and enhanced collaboration within MRC Members Country and within the LMB. The main implementations of the project activities were focused on discharge and sediment transport measurements in the mainstream and to a lesser extent in the tributaries. The project is getting finalized and therefore a final evaluation of the entire project’s scope will be performed.

The main project components and outcomes are:

- Regular discharge measurements on selected sites (cross-sections)
- Regular sediment sampling (suspended, bedload and bed material) – at the same sites
- Detailed bathymetric survey (river morphology) at one of the proposed mainstream dam sites,
- Providing equipment for the measurement and sampling activities,
- Providing equipment to sediment labs,
- Capacity building with an emphasis at the Line Agency Level of the Member Countries.

Each country is responsible for the operation and maintenance of its equipment and undertaking of the measurement and sampling activities with the support and co-ordination of the MRC.

**River Monitoring and Hydrological Stations along Mekong River**

It has been reported that in the Lower Mekong Basin, flow measurements reportedly started in the early 20th century. In the 1910s, discharge measurements at both the stations of Stung Treng in Cambodia and Vientiane in Laos commenced as a pioneer in this field, followed in the 1920s by the discharge measurements at Mukdahan in Thailand, Pakse in Laos and Kratie in Cambodia (Anonymous, 2004). It has also been reported that in Phnom Penh, such hydrological measurements also commenced in 1940. However, all these facts were known only through reference in presently available literature, because the data in those days have
not been stored and preserved properly. The Mekong Committee, as has already been mentioned, was established in 1957 and thereafter hydrological data throughout the Mekong mainstream have been observed and compiled consistently and continuously.

Water levels along different rivers are being monitored by MRC throughout the year which provides observations and forecasts for the LMB. (Source: http://www.mrcmekong.org/mrc/river-monitoring/ accessed on 5th September, 2018). This information is also provided to the MRC Member Countries as a service to the respective Governments so that these may be used as important inputs for ‘Disaster Forecasts and Warning Systems’. Citizens of these countries as also other organisations may get these information directly from Regional Flood Management and Mitigation Centre of MRC Secretariat

**Near Real Time Hydrological Stations**

A number of ‘Near Real Time’ Hydrological stations are there distributed over the entire Mekong Basin (Source : http://portal.mrcmekong.org/station_hydro accessed on 31.08.2018). In this case different parameters are displayed with a 15 minutes lag period. Hence, these stations are known as ‘Near Real Time’ hydrologic stations. The ‘Place marks’ on the map are indicative of the locations of the hydrological stations along LMB. These place marks are also indicative regarding the hydrological condition of the river on a particular day. In case the Flood Stage is more than the ‘Alarm Stage’, the colour of the place mark immediately changes to ‘Red’ indicating danger. In case the water level in the river is less than the ‘Alarm Stage’, the colour of the place mark will be green. When the water level in the river at that hydrological station is approaching ‘Alarm Stage’, the colour of the place mark becomes yellow. However, in case the water level in a river is much lower than the ‘Alarm Stage’, then the colour of place mark becomes white. Thus, just by looking at the map at any point of time, it can be understood regarding the hydrological condition of the river with respect to ‘Alarm Stage’ and ‘Flood Stage’.

Earlier, MRC used to provide updated water levels at every 2 hours interval. The information is aggregated to 24 hours of a day and 30 day periods for the month. However, at present there were altogether 47 stations for which the water level fluctuations were provided by MRC on Real Time Basis and upload those in the website of MRC. Out of these 47 stations, 2 are in China, 12 in Lao PDR, 11 in Thailand, 12 in Cambodia and 10 are in Vietnam.
Figure–6: Map of the Mekong Delta with the place marks indicating the hydrological station. The boundary of the Lower Mekong Delta has been indicated by thick blue line.

However, very recently, numbers of such Near Real Time Hydro-meteorological Centres have been increased to 59. In these stations, apart from water level monitoring, rainfall measurements are also going on. Except the Chinese Stations (which normally send data on hourly basis), all other stations send data to the website on 15 minutes interval. There is a map in the webpage (http://monitoring.mrcmekong.org/) showing all these 59 stations. The names of these stations are also indicated in a tabular format beside this map.

The Map showing the Near Real time Hydro-meteorological Stations is interactive in nature also. Putting the cursor on any of the place mark will immediately reveal Name of the Monitoring Station, Date and time of observation (as per the time zone of the country where the Monitoring Station is located), Name of the River, Country, Current Water Level etc. Thus, the map of the hydrological stations can reveal considerable data.

However, clicking on the name of the station on the adjoining table will open another window showing all details of that particular station. Apart from indicating the Date and time of observation (as per the time zone of the country where the Monitoring Station is located), Name of the River, Country, Current Water Level, it also reveals Alarm Stage Water Level, Flood Stage Water Level, Rainfall in last 15 minutes, in last 1 hour, 6 hours, 12 hours, 24 hours and total Rainfall in past 24 Hours from 7 am to 7 am basis.

Table – 7 : Details of 59 (Fifty Nine) Near Real time Hydrological Stations
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Position of the Station</th>
<th>Name of the Hydrological Stations</th>
<th>Name of the River</th>
<th>Code of the Station</th>
<th>Name of the Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Upper</td>
<td>Manan</td>
<td>Manan</td>
<td>092980</td>
<td>China</td>
</tr>
<tr>
<td>2.</td>
<td>Upper</td>
<td>Jinghong</td>
<td>Mekong</td>
<td>092600</td>
<td>China</td>
</tr>
<tr>
<td>3.</td>
<td>Lower</td>
<td>Sisophon</td>
<td>Stung Mongkolborey</td>
<td>530101</td>
<td>Cambodia</td>
</tr>
<tr>
<td>4.</td>
<td>Lower</td>
<td>Battambang</td>
<td>Sangker</td>
<td>550102</td>
<td>Cambodia</td>
</tr>
<tr>
<td>5.</td>
<td>Lower</td>
<td>Kompang Luong</td>
<td>Tonlesap</td>
<td>020106</td>
<td>Cambodia</td>
</tr>
<tr>
<td>6.</td>
<td>Lower</td>
<td>Kompong Thom</td>
<td>Stung San</td>
<td>610101</td>
<td>Cambodia</td>
</tr>
<tr>
<td>7.</td>
<td>Lower</td>
<td>Kratie</td>
<td>Mekong</td>
<td>014901</td>
<td>Cambodia</td>
</tr>
<tr>
<td>8.</td>
<td>Lower</td>
<td>Boribo</td>
<td>Stung Boribo</td>
<td>590101</td>
<td>Cambodia</td>
</tr>
<tr>
<td>9.</td>
<td>Lower</td>
<td>Prek Kdam</td>
<td>Tonlesap</td>
<td>020102</td>
<td>Cambodia</td>
</tr>
<tr>
<td>10.</td>
<td>Lower</td>
<td>Kampong Speu</td>
<td>Prek Thnot</td>
<td>640102</td>
<td>Cambodia</td>
</tr>
<tr>
<td>11.</td>
<td>Lower</td>
<td>Kampong Ampil</td>
<td>Tonle Touch</td>
<td>019905</td>
<td>Cambodia</td>
</tr>
<tr>
<td>12.</td>
<td>Lower</td>
<td>Chaktomuk</td>
<td>Bassac</td>
<td>033401</td>
<td>Cambodia</td>
</tr>
<tr>
<td>13.</td>
<td>Lower</td>
<td>Angkorborey</td>
<td>Stung Takeo</td>
<td>680103</td>
<td>Cambodia</td>
</tr>
<tr>
<td>14.</td>
<td>Lower</td>
<td>Lumphat</td>
<td>Sre Pok</td>
<td>450101</td>
<td>Cambodia</td>
</tr>
<tr>
<td>15.</td>
<td>Lower</td>
<td>Voeun Sai</td>
<td>Sesan</td>
<td>440102</td>
<td>Cambodia</td>
</tr>
<tr>
<td>16.</td>
<td>Lower</td>
<td>Stung Treng</td>
<td>Mekong</td>
<td>014501</td>
<td>Cambodia</td>
</tr>
<tr>
<td>17.</td>
<td>Lower</td>
<td>Siempang</td>
<td>Sekong</td>
<td>430102</td>
<td>Cambodia</td>
</tr>
<tr>
<td>18.</td>
<td>Lower</td>
<td>Chau Doc</td>
<td>Bassac</td>
<td>039801</td>
<td>Vietnam</td>
</tr>
<tr>
<td>19.</td>
<td>Lower</td>
<td>Tan Chau</td>
<td>Mekong</td>
<td>019803</td>
<td>Vietnam</td>
</tr>
<tr>
<td>20.</td>
<td>Lower</td>
<td>Vam Nao</td>
<td>Vam Nao</td>
<td>980601</td>
<td>Vietnam</td>
</tr>
<tr>
<td>21.</td>
<td>Lower</td>
<td>Vi Thanh</td>
<td>Xa No</td>
<td>902602</td>
<td>Vietnam</td>
</tr>
<tr>
<td>22.</td>
<td>Lower</td>
<td>Phung Hiep</td>
<td>Cai Con</td>
<td>902601</td>
<td>Vietnam</td>
</tr>
<tr>
<td>23.</td>
<td>Lower</td>
<td>Can Tho</td>
<td>Bassac</td>
<td>039803</td>
<td>Vietnam</td>
</tr>
<tr>
<td>24.</td>
<td>Lower</td>
<td>My Thuan</td>
<td>Mekong</td>
<td>019804</td>
<td>Vietnam</td>
</tr>
<tr>
<td>25.</td>
<td>Lower</td>
<td>Cho Lach</td>
<td>Ham Luong</td>
<td>908001</td>
<td>Vietnam</td>
</tr>
<tr>
<td>26.</td>
<td>Lower</td>
<td>Long Dinh</td>
<td>Xang</td>
<td>901503</td>
<td>Vietnam</td>
</tr>
<tr>
<td>27.</td>
<td>Lower</td>
<td>My Hoa</td>
<td>Ham Luong</td>
<td>908002</td>
<td>Vietnam</td>
</tr>
<tr>
<td>28.</td>
<td>Lower</td>
<td>Vam Kenh</td>
<td>Mekong</td>
<td>985203</td>
<td>Vietnam</td>
</tr>
<tr>
<td>29.</td>
<td>Lower</td>
<td>Duc Xuyen</td>
<td>Krong Kno</td>
<td>450701</td>
<td>Vietnam</td>
</tr>
<tr>
<td>30.</td>
<td>Lower</td>
<td>Giang Son</td>
<td>Krong Ana</td>
<td>450502</td>
<td>Vietnam</td>
</tr>
<tr>
<td>31.</td>
<td>Lower</td>
<td>Ban Don</td>
<td>Se Re Pok</td>
<td>451305</td>
<td>Vietnam</td>
</tr>
<tr>
<td>32.</td>
<td>Lower</td>
<td>Kontum</td>
<td>Dak Bla</td>
<td>440201</td>
<td>Vietnam</td>
</tr>
<tr>
<td>33.</td>
<td>Lower</td>
<td>Ban Veunkhen</td>
<td>Se Kong</td>
<td>430106</td>
<td>Lao PDR</td>
</tr>
<tr>
<td>34.</td>
<td>Lower</td>
<td>Pakse</td>
<td>Mekong</td>
<td>013901</td>
<td>Lao PDR</td>
</tr>
<tr>
<td>35.</td>
<td>Lower</td>
<td>Khongsedone</td>
<td>Nam Sedone</td>
<td>390102</td>
<td>Lao PDR</td>
</tr>
<tr>
<td>36.</td>
<td>Lower</td>
<td>Senuane</td>
<td>Sebangnuane</td>
<td>350106</td>
<td>Lao PDR</td>
</tr>
<tr>
<td>37.</td>
<td>Lower</td>
<td>Ban Kendone</td>
<td>Se Bang Hieng</td>
<td>350101</td>
<td>Lao PDR</td>
</tr>
<tr>
<td>38.</td>
<td>Lower</td>
<td>Phalane</td>
<td>Se Saugsoy</td>
<td>350102</td>
<td>Lao PDR</td>
</tr>
<tr>
<td>39.</td>
<td>Lower</td>
<td>Sopnam</td>
<td>Se Bang Hieng</td>
<td>350105</td>
<td>Lao PDR</td>
</tr>
<tr>
<td>40.</td>
<td>Lower</td>
<td>Se Bangfai</td>
<td>Se Bang Fai</td>
<td>320101</td>
<td>Lao PDR</td>
</tr>
<tr>
<td>41.</td>
<td>Lower</td>
<td>Mahaxai</td>
<td>Se Bang Fai</td>
<td>320107</td>
<td>Lao PDR</td>
</tr>
<tr>
<td>42.</td>
<td>Lower</td>
<td>Ban Nape</td>
<td>Nam Phao</td>
<td>270502</td>
<td>Lao PDR</td>
</tr>
<tr>
<td>43.</td>
<td>Lower</td>
<td>Phonesy</td>
<td>Nam Kading</td>
<td>270101</td>
<td>Lao PDR</td>
</tr>
<tr>
<td>No.</td>
<td>Station</td>
<td>River</td>
<td>Code</td>
<td>Country</td>
<td>Type</td>
</tr>
<tr>
<td>-----</td>
<td>---------</td>
<td>----------</td>
<td>----------</td>
<td>---------</td>
<td>----------</td>
</tr>
<tr>
<td>1</td>
<td>Ban Doi Hang</td>
<td>Nam Mae Kok</td>
<td>050106</td>
<td>Thailand</td>
<td>Normal</td>
</tr>
<tr>
<td>2</td>
<td>Ban Had Paeng</td>
<td>Nam Sonkhran</td>
<td>290102</td>
<td>Thailand</td>
<td>Normal</td>
</tr>
<tr>
<td>3</td>
<td>Ban Tha Kok Doeng</td>
<td>Nam Sonkhran</td>
<td>290102</td>
<td>Thailand</td>
<td>Normal</td>
</tr>
<tr>
<td>4</td>
<td>Chiang Khan</td>
<td>Mekong</td>
<td>019003</td>
<td>Thailand</td>
<td>Normal</td>
</tr>
<tr>
<td>5</td>
<td>Chiang Saen</td>
<td>Mekong</td>
<td>010501</td>
<td>Thailand</td>
<td>Normal</td>
</tr>
<tr>
<td>6</td>
<td>Chiang Khan</td>
<td>Mekong</td>
<td>013801</td>
<td>Thailand</td>
<td>Normal</td>
</tr>
<tr>
<td>7</td>
<td>Nakhon Phanom</td>
<td>Mekong</td>
<td>013101</td>
<td>Thailand</td>
<td>Normal</td>
</tr>
<tr>
<td>8</td>
<td>Nong Khai</td>
<td>Mekong</td>
<td>012001</td>
<td>Thailand</td>
<td>Normal</td>
</tr>
<tr>
<td>9</td>
<td>Wang Saphung</td>
<td>Nam Loei</td>
<td>150101</td>
<td>Thailand</td>
<td>Normal</td>
</tr>
<tr>
<td>10</td>
<td>Mukdahan</td>
<td>Mekong</td>
<td>013402</td>
<td>Thailand</td>
<td>Normal</td>
</tr>
<tr>
<td>11</td>
<td>Thoeng</td>
<td>Nam Mae Ing</td>
<td>070103</td>
<td>Thailand</td>
<td>Normal</td>
</tr>
</tbody>
</table>

Kratie in Cambodia, which was earlier not in the monitoring list, has been included this time raising the number to 59.

Figure – 7: Details of information provided for Near Real Time Hydro Meteorological Station in the website once anyone click on the name of any station (Source: http://monitoring.mrcmekong.org/station/050106 accessed on 06.09.2018)
Green N = Normal; Yellow N = Alarm; Red N = Flooded; White N = Data Not Available;  Green D = Normal (Drought station); Yellow D = Alarm (Drought Station);  Red D = Flooded (Drought Station); White D = Data Not Available (Drought Station);

Figure – 8 : Map showing locations of Near Real Time Hydro-meteorological Stations along LMB
Flood Forecasting

MRC makes ‘Flood Forecasting’ based on the water level as measured at different hydrological stations. This information is supplied as a service to the governments of the MRC Member States so that it may be used as a tool within existing national disaster forecast and warning systems (Source: [http://portal.mrcmekong.org/flood](http://portal.mrcmekong.org/flood) accessed on 06.09.2018). Other organisations and individuals wishing to receive this information directly from the MRC Secretariat should contact the Regional Flood Management and Mitigation Centre.

Water levels of different rivers under Mekong System are measured at 24 stations for giving Flood Forecasts as stated below:

Table : - 8 : Details of water level measurement stations for Flood Forecasting

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of the Forecasting Stations</th>
<th>Name of the Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Manan</td>
<td>China</td>
</tr>
<tr>
<td>2.</td>
<td>Jinghong</td>
<td>China</td>
</tr>
<tr>
<td>3.</td>
<td>Chiang Saen</td>
<td>Thailand</td>
</tr>
<tr>
<td>4.</td>
<td>Luang Prabang</td>
<td>Lao PDR</td>
</tr>
<tr>
<td>5.</td>
<td>Chiang Khan</td>
<td>Thailand</td>
</tr>
<tr>
<td>6.</td>
<td>Vientiane</td>
<td>Lao PDR</td>
</tr>
<tr>
<td>7.</td>
<td>Nong Khai</td>
<td>Thailand</td>
</tr>
<tr>
<td>8.</td>
<td>Paksane</td>
<td>Lao PDR</td>
</tr>
<tr>
<td>9.</td>
<td>Nakhon Phanom</td>
<td>Thailand</td>
</tr>
<tr>
<td>10.</td>
<td>Thakhek</td>
<td>Lao PDR</td>
</tr>
<tr>
<td>11.</td>
<td>Mukdahan</td>
<td>Thailand</td>
</tr>
<tr>
<td>12.</td>
<td>Savannakhet</td>
<td>Thailand</td>
</tr>
<tr>
<td>13.</td>
<td>Khong Chiam</td>
<td>Thailand</td>
</tr>
<tr>
<td>14.</td>
<td>Pakse</td>
<td>Lao PDR</td>
</tr>
<tr>
<td>15.</td>
<td>Stung Treng</td>
<td>Cambodia</td>
</tr>
<tr>
<td>16.</td>
<td>Kratie</td>
<td>Cambodia</td>
</tr>
<tr>
<td>17.</td>
<td>Kompong Cham</td>
<td>Cambodia</td>
</tr>
<tr>
<td>18.</td>
<td>Prek Kdam</td>
<td>Cambodia</td>
</tr>
<tr>
<td>19.</td>
<td>Phnom Penh Port</td>
<td>Cambodia</td>
</tr>
<tr>
<td>20.</td>
<td>Phnom Penh</td>
<td>Cambodia</td>
</tr>
<tr>
<td>21.</td>
<td>Neak Luong</td>
<td>Cambodia</td>
</tr>
<tr>
<td>Place</td>
<td>Country</td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>----------</td>
<td></td>
</tr>
<tr>
<td>Koh Khel</td>
<td>Cambodia</td>
<td></td>
</tr>
<tr>
<td>Tan Chau</td>
<td>Vietnam</td>
<td></td>
</tr>
<tr>
<td>Chau Doc</td>
<td>Vietnam</td>
<td></td>
</tr>
</tbody>
</table>

There is a specific webpage of Regional Flood Management and Mitigation Centre (http://ffw.mrcmekong.org/ accessed on 5th September, 2018) showing the place marks for the Flood Forecasting Stations. Putting the cursor on any of these place marks on any day will immediately reveal the condition of the water level in the river at that station on that day. The colours of the place marks immediately reveal the water level at that station. Green, Yellow, Red and White coloured place marks represent respectively Normal stage, Alarm Stage, Flood Stage and ‘Data Not Available’ respectively. Many of the hydrological stations are capable of delivering real time information also. MRC provides updated water levels every 2 hours. The information is summarised for 24 hours of any day and 30 day time periods for a month.

![Forecasting Station along mainstream](image)

Figure – 9: Position of the Forecasting Stations along Mainstream as shown in the website
Out of these stations, 13 Hydrological Stations are specially selected. These are Chiang Saen, Luang Prabang, Chiang Khan, Vientiane, Nakhon Phaom, Mukdahan, Pakse, Kratie, Kompong Cham, Phnom Penh, Tan Chau, Chau Doc and Stung Treng (Source: Website of MRC, http://portal.mrcmekong.org/low# accessed on 31.08.2018). At each of these stations daily observation of Mekong River water level is being continuously compared with the long term average so that the citizens can understand the actual danger out of the water level.

![Low Water Level in Dry Season at Luang Prabang, Compared with its Exceedance Probability (P%): 1961-2013 (Nov,2013-May,2014)](image)

Figure – 10 : Water Level Fluctuation curves at Luang Prabang Station for more than last 50 years so that water level on a specific day can be compared with average data

However this forecasting is normally being made with extreme caution since the station readings alone cannot indicate whether an area is flooded or not. Some low-lying areas may get flooded even before these measurements, taken from the riverbanks, and even before it reaches reach alarm level. Proper caution has been placed in the webpage that ‘Good forecasting requires putting information together from various sources.’ It has been advised to look into the station readings together with the maps on topography, land use and flood lines drawn on the maps as also the cross-section drawings of the rivers. Flash floods can happen along the major tributaries and creeks near the Mekong when heavy rainfall occurs.
and the river water starts to back up. These are very hard to predict. As a result, adequate statutory disclaimers have been used by MRC in this regard.

**Hydrology of Mekong River**

Unlike Sundarban delta, wherein the quantum of freshwater discharge is not well documented and for that matter not measured so far, Mekong hydrology is well documented due to rigorous and continuous studies being carried out by different agencies. It has been reported that the mean annual discharge of the Mekong is approximately 475 cubic kilometres (km$^3$) (MRC, 2005). 16% of this discharge amount is from China and only 2% is from Mynamer. Lao PDR, as a country, is the major contributor of water. Interestingly, the major left bank tributaries, particularly the tributaries that enter downstream of Vientiane – Nongkhai contributes about 60% of the discharge, as detailed in the following table:

**Table – 9 : Flow Contributions from different areas for mainstream reaches (MRC, 2005)**

<table>
<thead>
<tr>
<th>River Reach</th>
<th>Left Bank %</th>
<th>Right Bank %</th>
<th>Total %</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>China – Chiang Saen</td>
<td>16</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Luang Prabang – Chaing Khan</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Chiang Khan – Vientiane</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Vientiane – Nongkhai</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Nongkhai Nakhon Phanom</td>
<td>19</td>
<td>5</td>
<td>24</td>
</tr>
<tr>
<td>Nakhon Phanom – Mukdahan</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Mukdahan – Pakse</td>
<td>5</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>Pakse – Stung Treng</td>
<td>23</td>
<td>3</td>
<td>26</td>
</tr>
<tr>
<td>Stung Treng – Kratie</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>60</strong></td>
<td><strong>16</strong></td>
<td><strong>24</strong></td>
</tr>
</tbody>
</table>

The above table clearly pointed to the fact that the major flow contributions is from the left bank tributary systems in Lao PDR and the Se Kong and Se San Rivers which meet the Mekong River in between Pakse in Southern Laos and Kratie in Cambodia.

Flows at Chiang Saen entering the LMB from Yunnan make up about 15 percent of wet season flow at Kratie. This rises to 40% during the dry season, even for downstream. It is to be noted
that the major source of water flowing into the river at Yunnan comes from melting snow on the Tibetan Plateau. This volume of water is sometimes called the “Yunnan Component” and plays an important role in the low-flow hydrology of the lower mainstream (MRC, 2005). This is unique of Mekong River and has been studied over a long period of time. That is why there is significant concern regarding the construction of large scale reservoirs on the Mekong and its tributaries in Yunnan province, since it may have significant impact on the dry season hydrology of the lower stream. Mean annual flows along the Mekong River is described in the following table.

Table – 10: Lower Mekong Mainstream mean annual flow (1960 to 2004) at selected sites (MRC, 2005)

<table>
<thead>
<tr>
<th>Mainstream Site</th>
<th>Catchment area km²</th>
<th>Mean annual flow as</th>
<th>As % total Mekong</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Discharge cumecs</td>
<td>Volume km³</td>
</tr>
<tr>
<td>Chiang Saen</td>
<td>189,000</td>
<td>2,700</td>
<td>85</td>
</tr>
<tr>
<td>Luang Prabang</td>
<td>268,000</td>
<td>3,900</td>
<td>123</td>
</tr>
<tr>
<td>Chiang Khan</td>
<td>292,000</td>
<td>4,200</td>
<td>133</td>
</tr>
<tr>
<td>Vientiane</td>
<td>299,000</td>
<td>4,400</td>
<td>139</td>
</tr>
<tr>
<td>Nongkhai</td>
<td>302,000</td>
<td>4,500</td>
<td>142</td>
</tr>
<tr>
<td>Nakhon Phanom</td>
<td>373,000</td>
<td>7,100</td>
<td>224</td>
</tr>
<tr>
<td>Mukdahan</td>
<td>391,000</td>
<td>7,600</td>
<td>240</td>
</tr>
<tr>
<td>Pakse</td>
<td>545,000</td>
<td>9,700</td>
<td>306</td>
</tr>
<tr>
<td>Stung Treng</td>
<td>635,000</td>
<td>13,100</td>
<td>413</td>
</tr>
<tr>
<td>Kratie</td>
<td>646,000</td>
<td>13,200</td>
<td>416</td>
</tr>
<tr>
<td>BASIN TOTAL</td>
<td>760,000</td>
<td>14,500</td>
<td>457</td>
</tr>
</tbody>
</table>

There is considerable deforestation in the catchment area of the Mekong River during last 60 years due to many reasons, particularly political unrest, expansion of agricultural area,
population pressure etc. However, ‘it is still unclear how much impact land use changes have had on the hydrological regime of the Mekong. The removal of so much forest cover would be expected to result in changes in the rainfall-runoff relationship. ....... There is a lot of hydrological data, at least for the mainstream, but linking rainfall to stream flow is difficult, even on an annual timescale. However, no one has yet found any conclusive evidence in the 90 years of historical data for any significant changes in rainfall-runoff relationships’ (MRC, 2005).

It clearly demonstrates that in spite of such robust database, it is becoming difficult to establish relationship between two natural phenomena. This only indicates the pathetic condition of Sundarbans, since hardly any data exists there even on discharge of freshwater along different distributaries in Sundarbans.

**Kratie is generally regarded as the point in the Mekong system where the hydrology and hydrodynamics of the river change significantly** (MRC, 2005). Upstream from this point, the river generally flows within a clearly identifiable mainstream channel. In all but the most extreme flood years, this channel contains the full discharge with only local over-bank natural storage. Interestingly, Kratie is located at a distance of about 600 kilometres from the point of discharges of Mekong River at South China Sea. Downstream from Kratie, seasonal floodplain storage dominates the annual regime and there is significant movement of water between channels over flooded areas, the seasonal refilling of the Great Lake and the flow reversal in the Tonle Sap. There is extreme hydrodynamic complexity in both time and space and it becomes sometimes impossible to measure channel discharge. Water levels, not flow rates and volumes, determine the movement of water across the landscape. In case of Sundarbans, such point of significant changes in hydrology and hydrodynamics needs to be identified so as to understand the actual freshwater discharge along the Ganga – Padma River System.

Prior to 1960, Discharge Analysis along Lower Mekong River Basin was carried out by Harza Engineering Company. This Report by Harza Engineering Company was prepared for Committee for Coordination of Investigation of the Lower Mekong River Basin and the U.S. Agency for International Development (Bassin du Mekong Inferieur, debits pour 1959 et Annees Precedentes: Rapport/ Prepare par Harza Engineering Company pour le Committee de Coordination des Etudes sur le Bassin du Mekong Inferieur et l'Agence des Etats-Unis pour le Developpement International., Bassin du Mekong Inferieur, Debits pour 1959 et Annees Precedentes., Discharges prior to 1960, Mekong Basin) and published in 1962. Unfortunately, copy of this report is available only in hard copy and may be available from MRC Secretariat on request.

(Source: ...
Although MRC Secretariat claims to make data collection on different parameters for the Mekong River and its tributaries on regular basis, but the quantum of data as available does not point to a very bright picture (Source: http://portal.mrcmekong.org/datacollection accessed on 6th September, 2018). It appears that the data collected is quite scanty in nature and is of quite old. It may be possible that the webpage has not been updated properly which may lead to this confusion.

Table – 11 : Discharge & other data as available from MRC website

<table>
<thead>
<tr>
<th>Country</th>
<th>Discharge at Tributaries (stations)</th>
<th>Discharge at Mainstream (stations)</th>
<th>Sediment at Mainstream (stations)</th>
<th>SS GSA at Mainstream (stations)</th>
<th>Bedload, (stations)</th>
<th>Bed-material GSA (sites)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td><strong>25</strong></td>
<td><strong>16</strong></td>
<td><strong>16</strong></td>
<td><strong>8</strong></td>
<td><strong>3</strong></td>
<td><strong>64</strong></td>
</tr>
</tbody>
</table>

**Morphology Survey of Mekong River**

Till date MRC Secretariat does not have any well defined Morphology Survey of the river, except at pre-determined specific locations. However, The Navigation Programme at the MRC has requested assistance from the Information and Knowledge Management Programme (IKMP) to carry out baseline channel morphology surveys at a proposed rock removal site near Kong Phi Luang rapids in northern Thailand and Lao PDR (Source :
The planned rock removal is for the purpose of improving navigation safety. There are concerns that the removal of several bedrock obstructions from the channel may result in river incision or deposition in surrounding areas. This could potentially lead to exposure of other bedrock obstructions or detrimental effects on aquatic biota. However, a detailed baseline morphology survey planning is yet to be carried out. It has been so far planned in a schematic way. The aims of baseline channel morphology surveys are:

- To collect river channel cross-section profiles that can be compared to repeat surveys in the future to monitor and mitigate against potential morphological change;
- To provide input data to hydraulic and sediment transport models that can be used to predict channel incision and deposition. This would enable mitigation measures to be implemented prior to the removal of rocks.

Water Quality Measurement

MRC started water quality monitoring of Mekong River water from 1985 as per request of Member Countries. Initially, the water quality Monitoring programme started in Lao PDR, Thailand and Viet Nam. Cambodia joined the programme in 1993. Presently water quality monitoring is being carried out at 48 permanent monitoring stations, of which 11 are in Lao PDR, 8 in Thailand, 19 in Cambodia and 10 in Viet Nam. Samples of surface water are taken from the river mid-stream every two months, i.e. six times a year starting from February. Member Countries may increase the sampling frequency, sometimes 12 times a year, i.e. on monthly basis, as per latest agreement on ‘Procedures for Water Quality (PWQ) adopted in the year 2011. Water quality analysis is conducted in designated laboratories.

Out of these 48 sampling stations, 17 are on the mainstream, five on the major tributary Bassac River, and the remaining stations on other tributaries (MRC, 2018). At each station, 12 water quality parameters (temperature, pH, salinity, acidity, etc.) are analysed on a monthly basis, and another six parameters (calcium, magnesium, sodium, etc.) are examined during the wet season from April to October. The biochemical oxygen demand, another parameter, is assessed monthly at a few selected stations throughout the year. After the quality assessment, the samples are classified as “excellent”, “good”, “moderate”, “poor” or “very poor” for human health, and another similar five classifications for aquatic life. The samples are also analysed for irrigation use. These sampling data are submitted to the MRC Secretariat annually to verify and store in the database for public access. The MRC Secretariat further prepares a consolidated annual report, entitled the Lower Mekong Regional Water Quality
Monitoring Report, based on data from the main 22 stations of the Mekong and Bassac rivers (MRC, 2018).

On the basis of review of scientific literature and statistical analysis of the MRC data, a Water Quality Index has been designed based on a set of key water quality parameters. The Water Quality Index shows the pressure exerted by human activities on the water quality of the Mekong River. The Water Quality Index is calculated each year for 17 stations in the mainstream of the Mekong River from the Northern Lao PDR to the Mekong Delta.

An informative map on the water quality monitoring has been presented in the website. The map indicates the marker at the location of water quality monitoring stations and the colour of the marker is based on the Water Quality Index class for 2015, (Source: http://portal.mrcmekong.org/waterquality_map Accessed on 6th September, 2018)

Table – 12: Details of 22 stations and the water quality at these stations over seven years

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of Station</th>
<th>Station Id</th>
<th>River</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Houa Khong</td>
<td>H010500</td>
<td>Mekong</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td>C</td>
<td>A</td>
</tr>
<tr>
<td>2.</td>
<td>Chiang Sean</td>
<td>H010501</td>
<td>Mekong</td>
<td>B</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>3.</td>
<td>Luang Prabang</td>
<td>H011200</td>
<td>Mekong</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>4.</td>
<td>Vientiane</td>
<td>H011901</td>
<td>Mekong</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>6.</td>
<td>Pakse</td>
<td>H013900</td>
<td>Mekong</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>7.</td>
<td>Savannakhet</td>
<td>H013401</td>
<td>Mekong</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td>C</td>
<td>B</td>
</tr>
<tr>
<td>9.</td>
<td>Stung Trieng</td>
<td>H014501</td>
<td>Mekong</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>10.</td>
<td>Kratie</td>
<td>H014901</td>
<td>Mekong</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>11.</td>
<td>Kampong Cham</td>
<td>H020103</td>
<td>Mekong</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>12.</td>
<td>Chroy Chanvar</td>
<td>H019801</td>
<td>Mekong</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>13.</td>
<td>Takhmao</td>
<td>H033401</td>
<td>Mekong</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>A</td>
</tr>
<tr>
<td>14.</td>
<td>Koh Khel</td>
<td>H033402</td>
<td>Mekong</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>15.</td>
<td>Neak Loung</td>
<td>H019806</td>
<td>Mekong</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>16.</td>
<td>Koh Thom</td>
<td>H033403</td>
<td>Mekong</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>17.</td>
<td>Krom Samnor</td>
<td>H019807</td>
<td>Mekong</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>18.</td>
<td>Tan Chau</td>
<td>H019803</td>
<td>Mekong</td>
<td>C</td>
<td>B</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>19.</td>
<td>My Thuan</td>
<td>H019804</td>
<td>Mekong</td>
<td>B</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>20.</td>
<td>Chau Doc</td>
<td>H039801</td>
<td>Mekong</td>
<td>C</td>
<td>C</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>21.</td>
<td>My Tho</td>
<td>H019805</td>
<td>Mekong</td>
<td>C</td>
<td>C</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>22.</td>
<td>Can Tho</td>
<td>H039803</td>
<td>Mekong</td>
<td>B</td>
<td>C</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
</tbody>
</table>

Class A – No Impact; Class B – Slight Impact; Class C – Impact; Class D – Severe Impact

From the study, it is significant that none of these stations have severe impact as per the Water Quality Index. Although some of these stations have reached the point of ‘Impact’ but subsequently it was recovered. The map of water quality monitoring is presented below:
In addition to this water quality monitoring, MRC Secretariat also carries out measurement of Suspended Sediment Concentration (SSC). MRC has set up simple laboratories in all four member countries based on the agreement between the member countries so that these countries have the capability on analyzing suspended sediment concentration themselves using the same standardized analysis techniques and reporting in the same format for better quality-controlled and data use. For this, in Cambodia a simple laboratory was established at the Department of Hydrology and River Works, while in Lao PDR was established at the Department of Meteorology and Hydrology. In the Thailand, the laboratory in Chiang Sean was upgraded for SSC analyses, while in Viet Nam the laboratory was established at Chau Doc.
Additional Services of MRC for LMB

**Water Extent Mapping** is being carried out on regular basis using Remote Sensing Technique. The near-infrared band (NIR, MODIS band 2) provides the option for water and land boundary discrimination and thereby helps in mapping the water extent along the flood plains and wetlands on regular basis.

**Global Satellite Mapping of Precipitation (GsMAP)**: The amount of rainfall and its spatial distribution are important for water resources assessment, flood and drought prediction. The availability of several high resolution global satellite based rainfall products by various operating agencies, such as Global Satellite Mapping of Precipitation (GSMaP), CMORPH, TRMM Multi satellite Precipitation Analysis, can provide information on the amount of precipitation and its spatial distribution in such data sparse regions. Among these, GSMaP provides the highest spatial resolution satellite-based products at a fine temporal scale. In order to overcome the shortage of Ground Measuring Stations for rainfall, MRC accepted GSMaP with the technical support of JST (Japan Science and Technology) and Japan Aerospace Exploration Agency (JAXA) as Precipitation Measuring Mission.

**Keetch–Byram Drought Index (KBDI)**: Typically it is applied in potential wild-fire assessment in the United States. KBDI reflects water gain or loss within the upper soil column using mean annual rainfall, daily rainfall and daily maximum temperature as input parameters (Keeth & Byram, 1968). It is ranging from 0 (no drought) to 800 (extreme drought). Since LMB suffers from freshwater supply during dry seasons, MRC with the help of high resolution satellite data provides KBDI for different parts of LMB at the time of extreme summer to assist the Governments of the Member Countries to assess the actual drought situation over the areas under LMB.

**Normalize Difference Vegetation Index (NDVI)**: Based on the differential ratio of reflectance in two different spectral bands, which is a standardised remote sensing technique, NDVI actually represent the presence of green (in other words presence of vegetation) in an area. Based on MODIS data, MRC provides the NDVI over the entire LMB on regular basis to the Governments of the Member Countries.

**Vegetation Crop Index (VCI)**: VCI is an indicator of the vigor of vegetation which covers as a function of NDVI values for a given area. It assesses changes in the NDVI signal through time due to weather conditions, reducing the influence of ‘geographic’ (Kogan, 1990) or ‘ecosystem’ (Kogan, 1995) variables i.e. climate, soils, vegetation type and topography. MRC carries out VCI determination of LMB for making the assessment regarding crop production in the Member Countries and provide those data to the respective Government.
Environmental Management

Mekong is the world’s tenth largest river. It is the home to unique, rich and abundant natural resources such as *Pangasianodon gigas*, the Giant Mekong Catfish and *Orcaella brevirostris*, the Irrawaddy Dolphin (Source : [http://portal.mrcmekong.org/river-bio-monitoring](http://portal.mrcmekong.org/river-bio-monitoring) accessed on 6th September, 2018). These natural resources are under threat due to intensive irrigation for agriculture, a decline in traditional capture fisheries which is being replaced with semi-intensive to intensive pisciculture, extensive development along the LMB and the threat of climate change, impact of which is hardly understood at this moment. Thus, there exists a state of uncertainty regarding the fate of these natural resources.

MRC is looking into these aspects with focus on specific areas such as Climate Change Adaptation, Fisheries, wetlands and watershed management. The idea is to bring out country driven strategies with the aim to protect the environment and also to help people to adapt to environmental uncertainties in a more prepared manner.

Biodiversity

The Mekong basin is one of the richest biodiversity hotspot in the world. Recent estimates indicated that there is a rich biodiversity in LMB which includes approximately 20,000 plant species, 430 mammal species, 1,200 bird species, 800 reptile and amphibian species, and 850 fish species. New species in LMB is still getting discovered on regular basis (Source : [http://portal.mrcmekong.org/river-bio-monitoring](http://portal.mrcmekong.org/river-bio-monitoring) accessed on 6th September, 2018).

Even though there is abundance in concentration in number of different species, some of the species are declining in number and are even threatened due to unsustainable and reckless behaviour from the part of local residents. This includes even the Giant Catfish of Mekong, which has been declared as critically endangered species. Many important bird habitats have suffered due to wetland drainage, overgrazing, peat mining, reservoir construction, pesticide use and changes to agricultural practices. The Mekong Basin is home to some of the world’s most spectacular amphibians and reptiles, but unsustainable hunting and trading practices have decimated many of these populations.

For biodiversity conservation of Mekong River and the adjoining wetlands, MRC has undertaken a number of indigenous aquaculture projects under Fisheries Programme. In this programme, MRC encourages the local farmers to use indigenous species in aquaculture ‘to prevent the spread and dominance of non-native invasive species that threaten biodiversity’ (Source : [http://portal.mrcmekong.org/river-bio-monitoring](http://portal.mrcmekong.org/river-bio-monitoring) accessed on 6th September, 2018). There is another programme known as Basin Development Programme of MRC wherein an integrated approach of planning considering all aspects including environmental...
impacts, biodiversity loss and its mitigation measures is being implemented. In fact Basin Development Programme is an extensive programme which encompasses all these aspects and will be discussed subsequently.

The wetlands of LMB are famous for biodiversity. Tonle Sap River and the Great Lake of Cambodia, which has been declared as a UNESCO Biosphere Reserve, are particularly important. In fact, the Giant Catfish of Mekong travels all the way to Yunnan Province of China for spawning and thus the entire stretch of Mekong River and its different tributaries are important from the point of view of biodiversity conservation. Apart from providing normal eco-system services of wetlands such as sediment trapping, nutrient recycling and pollution removal, surface and ground water storage and carbon capture, these wetlands are the unique and irreplaceable habitats for countless species of fish, plants and animals, and essential food and water sources for millions of people in rural communities. MRC has initiated number of studies under the ‘Environment Programme’ and ‘Climate Change and Adaptation Initiative’ which are expected to provide important results and will help the policy makers to draw appropriate programmes for protecting these important ecosystems on a sustainable manner.

**Mangroves in Mekong Delta**

Mangroves are growing in 123 tropical and subtropical countries (Spadling et al, 2010). There are altogether 73 species of mangroves recognised as “True” mangroves. South-asia has been recognised as the most important and most diverse mangrove habitat. Out of the South-Asian countries, Vietnam had considerable mangrove coverage and still there is enough mangrove coverage especially in South Vietnam. Vietnam belongs to the Indo-Malesian class of the most bio-diverse region in the world (Alongi, 2002). Mangroves in Vietnam are primarily located in the Southern Vietnam in Mekong Delta and Ca Mau Province. Almost 70% of the mangroves of Vietnam are located in South Vietnam.

Due to long-term human impact, the density of mangrove vegetation has considerably changed along the whole southern Vietnamese coastline since the late 19th century, especially in the area of the Dong Nai River estuary, the Mekong delta and the adjacent peninsula towards Ca Mau (Mazda et al., 2002; Phan et al., 2015; Schwarzer et al, 2016). Approximately 42% of the total mangroves in Vietnam have disappeared from 1980 – 2005 (FAO, 2007).

It is estimated that nearly 40% of the mangrove forests in southern Vietnam were destroyed during the Vietnam War (1962–1971) (Phan and Hoang, 1993). Over 20% of about 600,000 ha of the total mangrove-forested regions of South Vietnam were defoliated in 1968 by chemical
spraying. According to FAO, Mangrove area decreased from 400,000 ha in 1960s to 73,000 hectares in 1990 due to the use of herbicides during the Indochina War, and conversion of mangroves for agriculture and aquaculture (Tuan, 2016). However, the area coverage was increased to 270,000 hectare in 2015 due to government and donor-funded planting efforts and mangrove protection policies.

Since 1975 mangrove forests initially recovered as a result of both natural regeneration and manual planting. However, in the 1980s and early 1990s the mangrove forests were again heavily destroyed because of timber overexploitation for construction, charcoal, and conversion of forest land into aquaculture-fisheries farming systems (Christensen et al, 2008). By the mid-1990s forest-felling bans were imposed and the forest enterprises were forced to replant and protect the forest rather than utilize it; however, by 1999 the felling ban ceased (Phan et al, 2015). Thus, the once-abundant mangrove forests in the Mekong coastal delta are becoming rapidly depleted. Especially along the Mekong eastern and south eastern coast,
mangrove degradation and rapid coastline erosion are observed at many locations (Phan et al, 2015). Conversion of mangroves for export-oriented intensive shrimp production remains a substantial threat in many areas (Tuan, 2016). There are many abandoned shrimp farms with potential for rehabilitation presently occurring in Ben Tre and Tra Vinh provinces in South Vietnam.

Table – 13 : Distribution and classification of Mangroves in Vietnam

<table>
<thead>
<tr>
<th>Area</th>
<th>Total area (ha)</th>
<th>Area by types of Forest (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Protection</td>
</tr>
<tr>
<td>Vietnam as a Country</td>
<td>209,741</td>
<td>115,950</td>
</tr>
<tr>
<td>Quang Ninh, Northern region</td>
<td>37,651</td>
<td>30,928</td>
</tr>
<tr>
<td>Central – northern region</td>
<td>1,885</td>
<td>1,341</td>
</tr>
<tr>
<td>Central – southern region</td>
<td>2</td>
<td>–</td>
</tr>
<tr>
<td>Southeast region</td>
<td>41,666</td>
<td>38,468</td>
</tr>
<tr>
<td>Mekong river delta</td>
<td>128,537</td>
<td>45,213</td>
</tr>
</tbody>
</table>

(Sources : Institute of Forest Inventory and Planning, Vietnam – FIPI)

There are different authorities for looking after mangrove protection and legislation in Vietnam. These are:

1) Ministry of Natural Resources and Environment (MONRE):
   - Responsible for land management, mapping and issuing land certificates
   - Has departmental offices (DoNREs) at the provisional and district levels for looking after the ground level scenarios

2) Ministry of Agriculture and Rural Development (MARD)
   - Responsible for forest and fisheries management, planning and allocation
   - Has departmental offices (DARDs) at the provincial and district levels

3) Provincial, district and commune People’s Committees
   - Represent the executive arm of the state
   - Evaluate and approve MONRE’s and MARD’s land and forest plans

Conservation approaches

The major challenge in Vietnam is that while coastal mangrove areas support large surrounding populations and diverse economic activities, these in turn drive mangrove loss (Slayde et al, 2010). The decline of Vietnam’s mangrove forests over the past 50 years
represents a serious environmental and social area of concern. Today, mangrove forests continue to be converted for development, agriculture, and aquaculture, and degraded by over-exploitation and pollution. As mangroves are lost, so are associated ecosystem services. Yet, financial resources to preserve mangroves are often lacking. This lack of funding can be attributed in part to a systematic undervaluation of mangrove ecosystems, as well as the reality that limited conservation funding must be shared between various conservation goals. Hence from a non-governmental approach, an approach known as “PES” (Payment for Ecosystem Services) was developed for the mangroves of Vietnam and was introduced among the conservationists of Vietnam, although not of much effect.

A number of Government initiatives have also been undertaken, as given below (after Salyde et al, 2010):

- In 2005: Law on Environmental Protection requires strategic environmental assessments for land use planning and forest development and protection. The Environmental Protection Law of 2005 also specifies that the trading of emissions credits with foreign buyers will be regulated by the Prime Minister.

- National Forestry Strategy for 2006-2020, aims to increase overall forest cover to 47% by 2020, including 5.68 million ha of protection forest and 2.16 ha of special use forest

- In 2008: The Biodiversity Law emphasizes the protection and conservation of biodiversity resources in the country. The law recognizes the environmental value of forests and mangroves and lays a foundation for the development of markets for ecosystem services.

- In 2008: Decision 380 outlines a pilot policy on payment for forest ecosystem services (PFES), under which ecosystem service users pay ecosystem service providers for the value of services provided by the forest.

- In 2009: The plan for mangrove restoration and development for 2008-2015, approved by the Prime Minister, sets a goal to increase the area of mangrove in Vietnam from 209,741 ha to 307,295 ha, mainly by planting. 29 coastal provinces are subject to this plan. Forest contracting and allocation to local households and communities are prioritized.

- In 2010: The National Strategy for Environmental Protection until 2020 and Vision Until 2020 sets a goal of increasing overall forest cover 43% by 2020, while
improving forest quality and restoring mangrove forest. The strategy recommends activities to increase mangrove areas to 80% of 1990 levels.

- In 2010: The master plan on development of the fisheries sector until 2020 and vision through 2020 has a goal of promoting sustainable extraction of aquatic products and sustainable aquaculture development across 1.4-1.5 million ha of surface water and production centers in the Red River Delta, southeast region, and Mekong River Delta

- Decree 119/2016/ND-CP – Policy on Coastal forest management, protection, rehabilitation and development in response to climate change. (23 August 2016, approved by Prime Minister).

In spite of these initiatives, the mangroves in Mekong Delta is under immense threat since the mangrove forests in Mekong Delta usually consist of a narrow strip only, sometimes as narrow as 100 m. Even these narrow strips of mangroves are getting squeezed. This mangrove squeeze is mainly due to the construction of sea dikes in a quest for the creation of space for cultivation and the prevention of salinity intrusion (Phan et al, 2015). There is a critical minimum width of a coastal mangrove forest strip to keep its ability to stay stable or, once surpassing the minimum width, to promote sedimentation. The larger the width the more efficient the attenuation of waves and currents will be, offering both a successful seedling and sedimentary environment. It has been pointed out that an average critical width of 140 m is found for the south eastern and eastern Mekong Delta coast as a minimum width to sustain a healthy mangrove forest (Phan et al, 2015). Unfortunately, the widths of the mangroves are getting constricted day by day, which is a real threat in the backdrop of climate change. Thus, there is a close similarity between the Mekong Delta mangroves and Sundarban Mangroves, since both will not get any further room on the landward side for backtracking in the face of climate change.

**Basin Development Planning**

The Lower Mekong Basin is experiencing a rapid development boom. Demand for food, water and energy will increase as a result of economic growth, industrialisation and urbanisation. Despite the surge in economic growth, millions of people still live in poverty (http://www.mrcmekong.org/topics/basin-planning/ accessed on 10.09.18). To a large
extent, sustainable basin planning in LMB is interconnected between poverty eradication and economic development.

Due to these complexities, there is a call for a coordinated or integrated approach to basin planning to secure the equitable use of the Mekong’s water resources. This approach is commonly referred to as Integrated Water Resources Management (IWRM) approach and aims to support effective and efficient management of water and related resources at the transboundary and cross-sector level.

The Mekong agreement tasks the MRC to promote optimal use of water and well-balanced development of the basin, and support the achievement of the Mekong’s full potential through the formulation of a basin development plan (MRC, 2018). Basin Development plan is the essential component of the Mekong Agreement. Lower Mekong Basin Development Strategy has been designed based on Integrated Water Resources Management Approach (Source: http://www.mrcmekong.org/topics/basin-planning/ accessed on 08.09.18).

It has been envisaged that integrated planning approaches in large and complex river basins can help ensure effective management and equitable use of water and related resources. This is very relevant for the Mekong River Basin and is the reason behind why an Integrated Water Resources Management (IWRM) is a cornerstone of the MRC’s approach to management planning on a basin-wide scale.

**Basin Development Strategy**

In response to the need to coordinate basin planning at the transboundary, or regional level, the LMB countries adopted the IWRM based ‘Basin Development Strategy’ (BDS) in 2011. The Strategy sets out how Mekong Countries will share, utilise, manage and conserve the Mekong water and related resources to achieve the goals of the 1995 Mekong Agreement. BDS was initially adopted for a period of five years from 2011 to 2015. The MRC Member Countries had developed shared understandings of the opportunities and risks of the national plans for water resources development along LMB and agreed on a number of Strategic Priorities to optimise the development opportunities and minimise uncertainty and risks associated with them. This provides incentives for the timely implementation of the agreed procedures under the 1995 Mekong Agreement (MRC, 2011). The MRC Council Members expected that implementation of the Strategy will promote regional cooperation for sustainable development of water resources and help to address climate change impacts and protect ecosystems and livelihoods. They called for the basin’s people to play a central role in the implementation of the Strategy and highlighted the need for capacity building and joint learning.
The IWRM-based Basin Development Strategy is a statement of the LMB countries setting out how they will share, utilise, manage and conserve water and related resources of the Mekong to achieve the goals of the Agreement for the Cooperation for the Sustainable Development of the Mekong River Basin, signed on 5 April 1995 (the Mekong Agreement, 1995).

The Strategy is part of the MRC’s commitment to regional cooperation under the 1995 Mekong Agreement, and in particular a response to Article 2 which calls for the formulation of a basin development plan. It provides initial directions for sustainable basin development and management that are subject to review and updating by MRC every five years.

The Strategy contributes to a wider adaptive planning process that links regional and national planning for sustainable development and management of the LMB. It considers projected development scenarios over a fifty-year period to create a twenty-year view of basin development and management. It provides an integrated basin perspective against which current and future national water resources development plans can be assessed to ensure an acceptable balance between economic, environmental and social outcomes in the LMB, and mutual benefits to the LMB countries, as required by the 1995 Mekong Agreement. The Strategy:

- defines the scope of opportunities for water resources development (hydropower, irrigation, water supply, flood and drought management), their associated risks and the actions needed to optimise opportunities and minimise risks;
- defines other water-related opportunities (fisheries, navigation, environment and ecosystems, watershed management); and
- provides a coordinated, participatory and transparent process that promotes sustainable development.

Need for the Strategy

Need for the strategy has been clearly mentioned in the BDP Document, 2011. It has been mentioned that ‘this Strategy has been developed during a time of significant change, where rapid, large-scale development of the river is already taking place. Hydropower dams constructed on the Lancang River in China (Lancang-Upper Mekong Basin) and on tributaries in the LMB are already changing the Mekong’s flow regime. There is increasing demand from riparian countries, project developers and stakeholders for the provision of an integrated basin perspective of national water resources development plans and their cumulative impacts. This is particularly true in a planning environment where private sector operations are a major driver of change’ (MRC, 2018).
The development of the strategy has been considered as an important milestone since for the first time, the countries have arrived - through discussions, information sharing and consultation - at a common understanding of each other’s plans for water resources development, drawing initial conclusions together on likely transboundary impacts, addressing each other’s concerns, developing a shared understanding of the opportunities and risks of water resources development and agreeing to a number of Strategic Priorities and actions to guide future decisions on basin development and management. It is a milestone in the history of cooperation under the framework of the Mekong River Commission (MRC), at a time when the Basin and the Mekong River itself, one of the world’s greatest rivers, are seeing significant changes. These include demographic, economic, climate and hydrological changes, influenced by national, regional and global drivers (MRC, 2018).

The Strategy on Opportunities and Associated Risks

There are many LMB water development opportunities that could bring significant benefits at national and, through cooperation, at regional levels. These opportunities also have significant risks and costs, which must be managed and mitigated, both at the national level, and where relevant, through cooperation at the transboundary level. The Strategy identifies the following opportunities and associated risks:

- Considerable potential for further hydropower development in the tributaries, particularly in Lao PDR and Cambodia, requiring harmonised social and environmental standards to ensure sustainability;
- Major potential to expand and intensify irrigated agricultural production to increase food security, including water use from the Mekong mainstream and to combat Delta saline intrusion, subject to LMB coordination and cooperation with other Mekong countries in the sound operation of existing and planned storage dams, to ensure increased, regulated and reliable dry season flows;
- Potential for some mainstream hydropower development, provided that uncertainties and risks are fully addressed and transboundary assessment and approval processes followed; although potential benefits are high, so are potential costs, including transboundary impacts; and
- Potential for other priority water-related developments (e.g. fisheries, navigation, flood and drought management, tourism, and environment and ecosystem management), as well as those beyond the water sector (e.g. other power generation options)

Strategy on Basin Development
The Strategy defines a process to move from development opportunities to implementation and sustainable development, including the definition of the following Strategic Priorities for Basin Development (MRC, 2011):

- Opportunities and risks of current developments addressed, including: coordination between LMB countries and cooperation with China achieved, to ensure increased dry season river flows; agreement on the maintenance of flows on the LMB mainstream implemented; and risks of committed projects managed;
- Irrigated agriculture for food security and poverty alleviation expanded and intensified;
- Environmental and social sustainability of hydropower development greatly enhanced;
- Essential knowledge acquired to address uncertainty and minimise risks of identified development opportunities, including knowledge on migration and adaptation of fish, trapping and transport of sediments and nutrients, changes in biodiversity, and social and livelihoods impacts;
- Options for sharing development benefits and risks identified;
- Climate Change Adaptation Strategy prepared and its implementation initiated; and
- Basin planning considerations integrated into national planning and regulatory systems.

Strategy on Basin Management

Under this specific head, Basin Management has been considered as an integral part of Basin Development for achieving sustainable development and the following points have been finalised:

- Basin objectives and management strategies defined for water-related sectors, including fisheries, flood and drought management, wetland management and navigation;
- National-level basic water resources management processes strengthened, including water resources monitoring, water use licensing, and data and information management;
- Basin-level water resources and related management processes strengthened, including the implementation of MRC Procedures, state of basin monitoring and reporting, project cycle monitoring, and enhanced stakeholder participation;
- Rigorous basin-wide environmental and social objectives and baseline indicators defined;
Water resources management capacity building programme implemented, linked to MRC’s overall initiatives and complementary to national capacity building activities

The strategy, thus defined was implemented through a well defined ‘Roadmap’ setting out priority actions, timeframes and outcomes of Strategy Implementation. Accordingly, the Roadmap, which was prepared in the year 2011 for a period of five years i.e. 2011-2016 was termed as ‘Basin Action Plan’ comprising a regional action plan and four complimentary and consistent national indicative plans, one per LMB country. It was envisaged that the national indicative plans would comprise those additional actions needed to supplement current national plans, in order to implement the Strategy; these actions would vary, reflecting individual country focus areas and priorities.

It was envisaged to update the strategy every five years based on the experience and target for the coming days. Subsequently, BDS was updated for next five years namely, 2016-2020 based on a long-term outlook and examines long-term needs for the development, of water resources (MRC, 2016). It focuses on achieving the sustainable development of the LMB and adapting national plans to address long-term needs and provide a comprehensive response to climate change and other challenges as the central point of the BDS for 2016-2020.

Four Focussed Key Result Areas have been considered in these five-year BDPs so that MRC can exert its influence to realize its mission and mandate as the regional river basin organisation to achieve the agreed strategic outcomes. The four focused areas are:

Table – 14: Four Focussed areas as adopted in Basin Development Plans of the LMB

<table>
<thead>
<tr>
<th>Focussed Areas</th>
<th>Envisaged Outcome</th>
</tr>
</thead>
</table>
| **Key Result Area 1:** Enhancement of national plans, projects and resources based on basin-wide perspectives | **Outcome 1:** Increased common understanding and application of evidence-based knowledge by policy makers and project planners  
**Outcome 2:** Environment management and sustainable water resources development optimised for basin-wide benefits by national sector planning agencies  
**Outcome 3:** Guidance for the development and management of water and related projects and resources shared and applied by national planning and implementing agencies |
| **Key Result Area 2:** Strengthening regional cooperation | **Outcome 4:** Effective and coherent implementation of MRC Procedures by the Member Countries  
**Outcome 5:** Effective dialogue and cooperation between Member Countries and strategic engagement |
<table>
<thead>
<tr>
<th><strong>Key Result Area 3:</strong></th>
<th><strong>Outcome 6:</strong> Basin-wide monitoring, forecasting, impact assessment and dissemination of results strengthened for better decision-making by Member Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Better monitoring and communication of the Basin conditions</td>
<td><strong>Key Result Area 4:</strong> Leaner River Basin Organisation <strong>Outcome 7:</strong> MRC transitioned to a more efficient and effective organisation in line with the Decentralisation Roadmap and related reform plans</td>
</tr>
</tbody>
</table>

This plan is now being implemented at this moment along LMB.

Thus, the Basin Development Plan for LMB can be cited as one of the best examples of ‘Water Diplomacy’ where the neighbouring countries have come together and framed strategies not for the sustainable utilisation of a river, but also for the entire region based on mutual trust and combined benefit where the river played the role of ‘common thread’.

**Meteorology**

There are numerous hydro-meteorological stations already existing and working in the Lower Mekong River Basin (Takao, 2002). All the four countries belonging to MRC are having line agencies for meteorological observation and data, as follows (MRC, 2014), as follows:

**Lao PDR:** Department of Meteorology and Hydrology (DMH), Ministry of Natural Resources and Environment

**Cambodia:** Department of Meteorology (DOM), Ministry of Water Resources and Meteorology

**Thailand:** (1) Thai Metrological Department (TMD), Ministry of Information and Communication Technology  
(2) Department of Water Resources (DWR), Ministry of Natural Resources and Environment

**Viet Nam:** National Hydro-Meteorological Service (NHMS)  
Ministry of Natural Resources and Environment (MONRE), National Centre for Hydro-Meteorological Service (NCHMS)

**Department of Meteorology and Hydrology (DMH), Lao PDR**
It works under Ministry of Natural Resources and Environment (MNROE). Lao PDR is a member of World Meteorological Organisation (WMO) since June, 1955 and is having Regional Association II (Asia) as per the website of WMO ([https://www.wmo.int/cpdb/lao-people-s-democratic-republic accessed on 11.09.18](https://www.wmo.int/cpdb/lao-people-s-democratic-republic)).

There are altogether 25 Surface and upper-air stations (OSCAR/ Surface) as per specific website page of Lao PDR of WMO website.

Table – 15 : Details of Surface and Upper Air Stations in Lao PDR

<table>
<thead>
<tr>
<th>Station Name</th>
<th>Index</th>
<th>Observing remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attopeu</td>
<td>48957</td>
<td>A, GOS, RBSN(S)</td>
</tr>
<tr>
<td>Bounneua</td>
<td>48921</td>
<td>A, GOS</td>
</tr>
<tr>
<td>Hat Dokeo</td>
<td>48942</td>
<td>AGRIMET, GOS</td>
</tr>
<tr>
<td>Houei–Sai</td>
<td>48926</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Luang Namtha (M. Sing)</td>
<td>48924</td>
<td>A, GOS, RBSN(S)</td>
</tr>
<tr>
<td>Luang – Prabang</td>
<td>48930</td>
<td>A, GOS, CLIMAT(C), RBCN, RBSN(S)</td>
</tr>
<tr>
<td>Nam Thane</td>
<td>48937</td>
<td>AGRIMET, GOS</td>
</tr>
<tr>
<td>Napheng (Pakcheng)</td>
<td>48943</td>
<td>AGRIMET, GOS</td>
</tr>
<tr>
<td>Oudomxay</td>
<td>48925</td>
<td>A, GOS, RBSN(S)</td>
</tr>
<tr>
<td>Paklay</td>
<td>48936</td>
<td>AGRIMET, GOS</td>
</tr>
<tr>
<td>Pakse</td>
<td>48955</td>
<td>A, GOS, CLIMAT(C), RBCN, RBSN(S)</td>
</tr>
<tr>
<td>Paksong</td>
<td>48956</td>
<td>AGRIMET, GOS</td>
</tr>
<tr>
<td>Parkxanh</td>
<td>48945</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Phonhong</td>
<td>48941</td>
<td>AGRIMET, GOS</td>
</tr>
<tr>
<td>Plaine Des Jarres (Xiengkhouang)</td>
<td>48935</td>
<td>A, GOS, RBSN(S)</td>
</tr>
<tr>
<td>Samneua</td>
<td>48928</td>
<td>GOS, RBSN(S)</td>
</tr>
</tbody>
</table>
## Station Name, Index, Observing remarks

<table>
<thead>
<tr>
<th>Station Name</th>
<th>Index</th>
<th>Observing remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saravane</td>
<td>48952</td>
<td>A, GOS, RBSN(S)</td>
</tr>
<tr>
<td>Savannakhet</td>
<td>48947</td>
<td>A, GOS, CLIMAT(C), RBCN, RBSN(S)</td>
</tr>
<tr>
<td>Sayaboury</td>
<td>48938</td>
<td>A, GOS, CLIMAT(C)</td>
</tr>
<tr>
<td>Seno</td>
<td>48948</td>
<td>A, GOS, CLIMAT(C)</td>
</tr>
<tr>
<td>Thakhek</td>
<td>48946</td>
<td>A, GOS, CLIMAT(C), RBSN(S)</td>
</tr>
<tr>
<td>Thangone</td>
<td>48944</td>
<td>AGRIMET, GOS</td>
</tr>
<tr>
<td>Vangvieng</td>
<td>48939</td>
<td>AGRIMET, GOS</td>
</tr>
<tr>
<td>Viengsay</td>
<td>48927</td>
<td>A, GOS, RBSN(S)</td>
</tr>
<tr>
<td>Vientiane</td>
<td>48940</td>
<td>A, GOS, CLIMAT(C), RBCN, RBSN(S)</td>
</tr>
</tbody>
</table>

WMO site maintains meteorological data of these stations of Lao PDR. Based on the data available from 1961 – 1990, WMO has produced station-wise charts (Source: [https://www.wmo.int/cpdb/lao-people-s-democratic-republic accessed on 11.09.2018](https://www.wmo.int/cpdb/lao-people-s-democratic-republic accessed on 11.09.2018)) as follows:

![Chart](image)

*Figure – 13: Chart created at the WMO website based on the data from 1960 – 1990*
However, not much information regarding meteorological system is available from their website (http://www.newcdmh.com/newc/index.php accessed on 11.09.18)

A ‘National Early Warning Centre’ (NEWC) is in operation under DMH in a project mode. Its objective has been indicated as ‘The Greater Mekong Sub-Region (GMS) Flood and Drought Management and Mitigation Project supports the Government of Lao PDR to undertake structural and non-structural measures to prepare for and manage disaster risks linked to floods and droughts. Project interventions, as formulated in the Terms of reference are: (i) enhance regional data and knowledge for the management of floods and droughts; (ii) upgrade or develop water management infrastructure; and (iii) prepare communities to manage disasters such as flood and drought and adapt to climate change.’ (Source: http://www.newcdmh.com/newc/index.php/about-us/national-early-warning-centre-newc accessed on 11.09.18).

It has been indicated that reliable hydro-meteorological data and the development of an effective early warning system are essential to mitigate the losses from flood and drought disasters. To achieve this goal, improvement of the hydro-meteorological network, effective data transmission and management system, development of forecasting models, early warning and public awareness, as well as effective communication system are necessary, which have been included as the target for the DMH.
Two priority basins for hydro-meteorological data collection and early warning system development are: The Sebangfai and the Sebanghieng River Basins. These two basins are among the most flood affected river basins in Lao PDR.

There is an Early Warning System Mechanism already adopted by DMH. The Early Warning System Mechanisms are an integrated set of steps starting from the (i) data acquisition from the field stations, (ii) the treatment of the information through the operational hydro-meteorological model and (iii) the delivery of the information to the relevant authorities with appropriate messages and appropriate supports.

The data processing system, the modelling tools and the web portal have been integrated in order to get a process that is automatized to the extent possible for providing information to the end-users in a timely and reliable manner.

There are altogether 14 hydrological stations along Sebangfai and Sebanghiang River basins, out of which eight stations have been indicated in the website as Automatic Hydrological Stations, as below:

1) Sobnam
2) Xelanong
3) Ban Dong
4) Sethamouak
5) Keng Done
6) Xieng Hom
7) Ban Kengkok
8) Dong Hene

There are two Automatic Weather Stations (AWS) which are 1) Savannakhet-Seno and 2) Dong Hen. The locations of all the Automatic Hydrological Stations and AWS have been shown on the map and displayed on the website.

However, it is to be noted that Department of Meteorology and Hydrology does not have any specific programme with focus on Mekong River, although almost the entire Lao PDR is included within LMB.

Department of Meteorology (DOM), Cambodia
The **Ministry of Water Resources and Meteorology** (MOWRAM) was created in Cambodia the year 1999. Its main objective is to address political and scientific issues, as stated below:

- Establish the position of the government in terms of political and strategic orientations with respect to both the water resources availability for local development, and its sustainability at national and international scale,
- Carry out scientific research on the potential of underground and surface water resources to establish scientific knowledge on the topic,
- Set directions and roadmap at short, medium and long term with respect to water consumption to fulfil the needs of the country’s development, of the industry and preserve those of urban and rural populations,
- Control and monitor all activities consuming water to mitigate incurred risks,
- Prepare and draft laws and regulations linked to the use of water and control procedures,
- Gather documents and build a technical database about climate and hydrology regarding water uses nationally and abroad, find return on investment for the scientific research,
- Raise the awareness of the industry, NGOs, civilian communities and populations about the development and the exploitation of water resources, and advise them technically on the matter,
- Communicate and validate innovative techniques with respect to the use of water use and its treatments,
- Collaborate and participate in the management of the Mekong Basin, considering both management of water resources and meteorology.

The ministry is composed of ten departments and one technical centre:

- Administration and Human Resources
- Planning and International Cooperation
- Finance
- Management and conservation of water resources
- Hydrology and river work
- **Meteorology**
- Irrigation
- Clean water and sanitation
- Engineering
- Community of water users
Technical center of irrigation and meteorology.
The ministry has local representatives called "Provincial Department of MOWRAM", in the 24 provinces to ensure local actions. Among 1400 employees working at the ministry, 662 people are located in Phnom Penh.

**Missions of the Department of Meteorology:**

- To prepare short, medium and long term plans for rehabilitation and development of meteorology abilities throughout the country.
- To establish and manage the Cambodian meteorological stations.
- To provide weather forecast in short and long time range for all concerned sectors.
- To predict abnormal meteorological phenomenon and emit alert to enable the setting up of protective procedures.
- To raise knowledge and communicate with national and international actors on meteorology technologies.
- To strengthen and broaden Cambodian cooperation on meteorology with meteorological organizations, United Nation agencies and World Meteorological Organization.
- To prepare annual reports on the situation of meteorology in the Kingdom of Cambodia.

**Radar Station as Weather Station**

In June 2010, Government of Cambodia decided in modernization of meteorological predications in Cambodia. The objective is to enable the department of meteorology to produce and broadcast weather forecasts thanks to high-performance facilities.

Following this decision, a "Doppler weather radar meteo 650C" was installed. The Radar Station **TECHO SE** is located in Phnom Penh, and started operation in April, 2012. The height of the hexagonal building is 50.60 m (for a total height of 60.60 m if one includes the radar protection ball). It has a diameter of 24.48 m, 13 floors with 5 dedicated to offices and to the weather prediction centre.

Cambodia is a member of WMO from November, 1955 and is partner of Regional Association II i.e. Asia. There are altogether 24 Surface and upper-air stations (OSCAR/ Surface) as per specific website page of Cambodia in WMO website (https://www.wmo.int/cpdb/cambodia), as below:

Table – 16 : Details of Surface and Upper Air Stations in Cambodia
<table>
<thead>
<tr>
<th>Station Name</th>
<th>Index</th>
<th>Observing remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banteay Meanchey</td>
<td>48969</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Battambang</td>
<td>48962</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Kampot</td>
<td>48985</td>
<td>GOS, CLIMAT(C), RBSN(S)</td>
</tr>
<tr>
<td>Kandal</td>
<td>48990</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Koh Kong</td>
<td>48986</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Kompong Chnang</td>
<td>48967</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Kompong Speu</td>
<td>48992</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Kompong Thom</td>
<td>48965</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Kompong-Cham</td>
<td>48995</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Kos Kong</td>
<td>48982</td>
<td>GOS</td>
</tr>
<tr>
<td>Kratie</td>
<td>48970</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Mondol Kiri</td>
<td>48971</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Pailin</td>
<td>48963</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Phnom-Penh (Khmough)</td>
<td>48991</td>
<td>A, WT, GOS, CLIMAT(C), RBCN, RBSN(S)</td>
</tr>
<tr>
<td>Preah Vihear</td>
<td>48964</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Prey Veng</td>
<td>48997</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Pursat</td>
<td>48968</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Rattanakiri</td>
<td>48973</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Sen Monorom</td>
<td>48978</td>
<td>GOS</td>
</tr>
<tr>
<td>Siemreap</td>
<td>48966</td>
<td>A, GOS, CLIMAT(C), RBCN, RBSN(S)</td>
</tr>
<tr>
<td>Sihanouk Ville</td>
<td>48983</td>
<td>C, GOS, RBSN(S)</td>
</tr>
<tr>
<td>Stung Treng</td>
<td>48972</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Station Name</td>
<td>Index</td>
<td>Observing remarks</td>
</tr>
<tr>
<td>--------------</td>
<td>-------</td>
<td>------------------</td>
</tr>
<tr>
<td>Svay Rieng</td>
<td>48998</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Takeo</td>
<td>48993</td>
<td>GOS, RBSN(S)</td>
</tr>
</tbody>
</table>

In the website as also related documents, no focus has been observed on LMB by Cambodia, although most of these stations including the Radar Station is located on LMB. That may be reason for not mentioning LMB separately.

**Thai Meteorological Department (TMD), Thailand**

In 1905, meteorology was first introduced to Thailand in the field of navigation (Source: [https://www.tmd.go.th/en/](https://www.tmd.go.th/en/) accessed on 11.09.2018). Thereafter, meteorology was continuously used for advancement in navigation also. Thailand’s first Meteorological Service, known as the Meteorological and Statistics Section, was established in 1923, attached to the Water Management Division of the Royal Irrigation Department under the Ministry of Lands and Agriculture. Observation Centres were set up in many provinces for the collection of rainfall and temperature data, for construction of water gates and for drainage and reservoir management.

In August 1936, the Meteorological and Statistics Section of the Royal Irrigation Department was transferred to the Hydrographic Department of the Royal Thai Navy, being currently known as the Meteorological Division. Realizing its increasing importance for various national activities, the Meteorological Division was promoted to the level of a Department in June 1942. Later, the Department was transferred from the Royal Thai Navy to the Office of the Prime Minister in the year 1962.

Awareness regarding increasing importance of the application of meteorology to various fields of human activity, particularly agriculture, water resources development, land transportation, shipping and aviation, and also the increasing responsibilities of many Government units under the Office of the Prime Minister, resulted in the Meteorological Department being transferred from the jurisdiction of the Prime Minister to that of the Ministry of Transport and Communications in October, 1972. In the year 2002, the Thai Government reformed the Government System, resulting in the Meteorological Department being transferred to be under the Ministry of Information and Communication Technology starting from 3rd of October, 2002, which indicates that the Government’s willingness to communicate the meteorological information to public end on a fast mode.
The involvement of the Department in the international aspects of meteorology has grown steadily over the years since its adherence to the Convention of the World Meteorological Organization (WMO) in 1949. It is worth mentioning that when it joined WMO on 13 May, 1949, Thailand became the nineteenth member of the organization. Today there are 178. Its participation in many of the programmes of WMO, and notably the World Weather Watch (WWW) and the Tropical Cyclone Programme (TCP), has ensured its continuing development in keeping abreast of the latest technological advances. Thus, the importance of meteorology and its practice are quite known to Thailand over a long period of time.

Vision and Mission of TMD

TMD’s missions have been designed to carry on meteorological administrations and managements with two vital objectives: (1) the best economic, social, agricultural and industrial benefits and (2) protection of human lives and properties possessed by public members, private sectors and governmental units against natural disasters. It has been entrusted by the Thai Government to perform the following five duties:

1. To supply weather forecasts for the entire country and publicize disaster warnings to fulfil the requirement from administration and management in natural disaster mitigation
2. To build people’s awareness toward natural disasters; enable them to perform correct surviving practices; and reduce effects from natural disasters by using modern technologies together with IT services
3. To become the meteorological IT data and service centre at the national level for users in any ventures
4. To improve and develop the Departments research works
5. To strengthen the Department’s roles in international cooperation concerning meteorology and environment with the purpose of profound comprehension on changing world situation.

According to the government gazette, published in 2002, the Thai Meteorological Department comprises 2 units, 1 office, 2 divisions, 4 bureaux, and 5 centres. The Meteorological Department, which is responsible for looking after climate related issues, plays important role in weather monitoring, study and analyze the climate at all times as well as improving and developing the climate forecast to be more effective. It also publishes climate information and advises on climate change and related agencies for the benefit of planning and decision making, to alleviate the impact of natural disasters and climate change and the loss of the least. Meteorological Department has set up a climate centre...
as an internal agency for carrying out studies and research on the current climate change situation.

**Climate Centre**

There are important climate variables that affect the environment and the lives of humans, animals and other organisms. The Climate Centre serves as the centre and source of climate information in the country to disseminate climate information to the public and relevant agencies for the benefit of planning and decision making.

The Climate Centre has been entrusted with the following responsibilities:

- Follow up, analyze and report local weather in Thailand and include the impact of weather in those reports
- Preparation and dissemination of news and academic papers on climate, meteorology.
- Long term weather prediction by analyzing the output from the model, meteorological and climatic data
- Assessing Climate change by researching and developing technologies suitable for Thailand.
- Cooperate with relevant agencies both in and abroad to follow the progress
- Develop long-term weather forecasts and climate change
- Act as a source of climate information in Thailand, by collecting, compiling, and producing climate information reports
- Provides information services to the general public and related organisations/institutions

Climate Centre operates under the WMO framework and works in the following fields:

1. Climate data management and climate change management
2. Climate monitoring and assessment
3. Climate product and service Productivity and climate services
4. Climate change information for adaptation and risk management

It also works with the following strategies:

**Strategy 1:** Leading technology transfer in the development of climate change models.

**Strategy 2:** Promote proactively on climate change

**Strategy 3:** Create a service receiver network on weather condition
The website of Climate Centre is quite rich. There is a detail discussion in the webpage in a separate section on “Climate Change of the World and of Thailand”. On a dropdown menu basis, the following issues are covered, as follows:

a) Climate Change  
b) Green house effect  
c) Global Warming  
d) Impact of Climate Change on human Hygiene  
e) Impact of climate change on food production  
f) Climate change and climate change in the World and Thailand  
g) Impact of Climate change on the rise of sea level  
h) Climate change projection product by Metview  
i) Climate Change Data Kit  
j) Climate Change Poster etc.

Although these sections are all written in local language, but it provides the option for online translation in English and thereby helps in understanding of the write-ups. The write-ups here are mostly generic in nature, but extensive and thereby will help the common people and the stakeholders to understand these issues, which is extremely important in the present backdrop of climate change.

Similarly, there are other sections like “Climate Monitoring” describing issues like:

a) Climate statistics for the period of 30 years 1981 – 2010  
b) Climate Statistics  
c) Provincial Weather  
d) Tropical cyclone statistics  
e) Tropical Statistics (map)

However most of the write up, except the ‘Map’ section, has been written in local language and without any provision of online translation (PDF documents), which makes it difficult to understand by the others belonging to other part of the Globe.

Under “Weather summary” section, the following issues are described in local language without any option for translation, as follows:

a) Weekly Weather Summary (Every Monday)  
b) 7 Day Weather Summary (Every Friday)  
c) Monthly Weather Summary
d) Annual weather summary

However, since these are written in local language, these can be easily understood by the local people, who are the main stakeholders.

“Long term weather forecast section” deals with the following issues, once again in Thai language:

a) Weather Forecast
b) 4 week weather forecast
c) 1 month weather forecast
d) 3-month weather forecast
e) Seasonal weather forecast
f) Weather Forecast for Tourism

There are also sections like ‘Modelling Climate Forecast’, ‘Natural phenomena’, ‘Climate Index’, ‘Articles/Academic Documents’, ‘Report on Natural Disasters in the country’ ‘Online Questionnaire’ etc.

Under Climate Section (Source: https://www.tmd.go.th/en/accessed on 11.09.18), there are four subsections namely,

a) Daily Weather Summary
b) Weekly Weather Summary
c) Monthly Weather Summary
d) Yearly Weather Summary

In Weekly Weather Summary, weather conditions of different parts of the country have been described like (i) Northern Part, (ii) North-eastern Part, (iii) Central Part, (iv) Eastern Part, (v) Southern Part (East Coast), (vi) Southern Part (West Coast) and (vii) Metropolitan (Source: https://www.tmd.go.th/en/climate.php?FileID=3 accessed on 11.09.2018)

Under Weather Section, General Weather Situation and other details of (i) Thailand (overall scenario), (ii) Northern, (iii) North-eastern, (iv) Central, (v) East, (vi) Southern (East Coast) and (vii) Southern (West Coast).

There are altogether 24 (Twenty Four) number of Radars under Thai Meteorological Department which have been given in TMD website. These Radar Stations are:

1. Chiang Rai
2. Lamphun
3. Nan (120)
4. Nan (240)  
5. Phitsanulok  
6. Khon Kaen  
7. Sakon Nakhon  
8. Uban Ratchathani (120)  
9. Uban Ratchathani (240)  
10. Surin (Mobile Radar)  
11. Chainat  
12. Samut Songkharam (120)  
13. Samut Songkhram (240)  
14. Suvarnabhumi (120)  
15. Suvarnabhumi (240)  
16. Rayong  
17. Huahin  
18. Chumphon  
19. Surat Thani  
20. Phuket (120)  
21. Phuket (240)  
22. Krabi  
23. Sathing Phra  
24. Narathiwat

Individually, all these Radar Stations have long range and thus the weather prediction system of TMD is quite robust.
In some cases even the area coverage by the individual radars are also written in Thai language and only understandable by the local people.

Simultaneously with it, there is a specific section known as ‘TMD Radar Loop’, wherein the movements of Electromagnetic waves from and to the radar have been displayed in an animated manner for altogether 18 Radar stations, out of the 24 stations mentioned above.
Figure – 16: Area Coverage of the Radar System at Suvarnabhumi (Source: http://weather.tmd.go.th/svp120.php accessed on 13.09.2018); written in Thai Language

The website also displays five more information under a dropdown section entitled “TMD Radar Composite”, as given below:

1. Nationwide Composite
2. Nationwide Composite Loop
3. Nationwide QPE
4. Nationwide QPE Loop
5. Nationwide QPE ASCII File

However, whatever drawings and charts are there under these five sections are all in Thai language and so it became difficult to understand by anyone who does not know Thai Language.
It is interesting to note that there are two other sections of Radar are described in the website. These are (1) Bangkok Radar (under which two more radars have been mentioned – Nongchok and Nongkhame) and (2) Rainmaking Radar (under which five more radars have been mentioned – Omkoi, Rong Kwang, In Buri, Pimai and Sattahip). These seven radars do not belong to normal weather radar system of Thailand but are ‘the result of radar stations under the jurisdiction of Bangkok and the Royal Rain and Agricultural Aviation respectively’ (Source: http://weather.tmd.go.th/disclaimer.html accessed on 13.09.18) incidentally, this particular project is famous and innovative for making artificial rain as initiated by the King of Thailand in the year 1955 and has recorded considerable success.

Weather Warning Announcements are normally published four times a day, i.e. at 5-00 am, 11-00 am, 5-00 pm and 11-00 pm (Local Time) on regular basis. However, all those bulletins available in the website are in Thai Language.

**Department of Water Resources, Thailand**

Department of Water Resources, Government of Thailand (Webpage: [http://news.dwr.go.th/index.php](http://news.dwr.go.th/index.php)) is also actively involved in providing meteorological services. As the name signifies, the entire service provided by the department is related to Water related service only. The official Mission of the department is to create ‘Integrated Water Management System – at National and International Level’.

The contents of the website are mainly in Thai Language and thus it is difficult to go through the documents loaded in the website. However, the headings of different sections from the website can only be readable. As per the headings, it seems that there is a specific section with the name “Water Situation” (webpage: [http://news.dwr.go.th/situation.php?category_id=26](http://news.dwr.go.th/situation.php?category_id=26)). Within this section, on each day one or two bulletins on water situation of the country has been uploaded to inform the citizens. Although, numbers of such reports are there including the recent ones, it was not possible to understand any of these reports due to language barrier.

Another webpage ([http://news.dwr.go.th/situation.php?category_id=23](http://news.dwr.go.th/situation.php?category_id=23)) on “Toll Station Report” described the water availability status in different watersheds like Yom Watershed, Nan Watershed, Songkhla Lake Watershed, Bang Pakong River Basin – Prachin Buri, Chao Phraya River Basin, Sakae Krang River Basin, Pa Sak Waterfall, Wang River Basin and Ping River Basin etc. Statuses of water in all these nine watersheds are uploaded on a single day, i.e. 11th September, 2018. Each of these reports is quite detail in nature and seems to be informative also since average size of these reports are 15 to 20 pages in length containing maps, charts and graphs, although could not be understood due to language barrier.
The webpage entitled “CCTV Water Level” (http://news.dwr.go.th/situation.php?category_id=21) describes the condition of water as recorded by CCTV in different rivers as recorded from the bridges over these rivers at several points on daily basis. Every day, a detail report is prepared with the CCTV pictures at different points from different bridges, which is uploaded in the webpage. As for example, on 11th September, pictures of water level at 45 (Forty Five) different bridges spreading over entire Thailand have been published, although could not be understood due to language problem.

Early warning webpage (http://news.dwr.go.th/situation.php?category_id=61) publishes the “Report on the status of Rainfall and Precipitation” on a specific day, also in the local language. In the webpage “24 hour water monitoring report” (http://news.dwr.go.th/situation.php?category_id=49) Water monitoring report for last 24 hours are uploaded two times at morning 8-00 hrs and at 3-00 pm on each day. Some reference of Mekong River Commission (MRC) is also there, but all the reports are in Thai language only.

DWR also has a ‘Drought Management’ (http://news.dwr.go.th/situation.php?category_id=31) programme also. It seems that in certain years, when such situation arises, then the department initiates such programme and prepare the ‘Integrated Water Situation Plan’ and/or ‘Drought Management’ as happened during February’2015 and April’2012 respectively. However the contents of these reports could not be ascertained.

Thus, it seems that Department of Water Resources also provides a number of hydro-meteorological services which are important for water resources of Thailand as also for the Mekong River, which is the major river in this country.

**National Hydro-Meteorological Service of Viet Nam**

The National Hydro-Meteorological Service (NHMS) is a state operational institution under Ministry of Natural Resources and Environment (MONRE) and works to assist the country in managing and exploiting the national hydro-meteorological station networks (including meteorological and hydrological basic investigations, forecasts, documentation), carrying out observations on air and water environment for disaster prevention and preparedness, socio-economic development, to ensure security and defence etc. all over the country.

Vietnam is a member of WMO since July, 1975. National Hydro-meteorological Service is the Hydrological advisor and Meteorological Authority and is the Meteorological Service Provider in Vietnam as per website of WMO.
There are altogether 8 (eight) Institutional units under NHMS of Vietnam, which are: i) National Centre of Hydro-Meteorological Forecasting (NCHMF), ii) Hydrological, meteorological and environmental station network centre, (iii) Aero-meteorological observatory, (iv) Center for Hydrological and meteorological Information Technology, (v) Hydro-meteorological Data Centre, (vi) Center of Technological Application and Training for Hydro-meteorology and Environment, (vii) Hydrometeorology Survey Department and (viii) Scientific and Technical Hydro-Meteorological Journal. There are also 9 (nine) Regional Hydro-meteorological centres working under NHMS. These are (1) Tay Bac (in Northwest), (2) Viet Bac (in Mid Northern), (3) Dang Bac (in Northeast), (4) Dong Bang Bac Bo (in Red River Delta), (5) Bac Trung Bo (in North Central), (6) Trung Trung Bo (in South Central), (7) Nam Trung Bo (in South Central), (8) Tay Nguyen (in Central Highland) and Nam Bo (in Southern Vietnam). There are 54 provincial hydro-meteorological forecasting centres and observation station networks also distributed all over Viet Nam.

In Vietnam, altogether 174 Meteorological stations are there, divided into 3 classes:

**Class 1 Type:** Weather watch: 24/24 hrs

Observation parameters: Wind (direction &speed), Rain fall, Air pressure, Air Temperature, Humidity, Sunshine, Evaporations, Land Temperature (ground and deep layers); Cloud, Visibility, Ground conditions, Radiation (at some stations).

Data collection & transmission: 8 times/day

**Class 2 Type:** Weather Watch: 24/24 hrs

Observation Parameter : Same as class 1, but not doing the observation of radiation, air pressure (at some stations)

Data collection & transmission: 4 times/day

**Class 3:** Weather Watch: 24/24 hrs

Observation Parameter : Same as class 2, but not doing the observation of air pressure.

Data collection & Transmission: 2 times/day

Out of these 174 stations in Vietnam, number of different class of stations is as follows:

**Total:** 174 Stations

- Class 1 : 58
- Class 2 : 70
- Class 3 : 46
National Centre for Hydro-Meteorological Forecasting (NCHMF) is a governmental organization belonging to Vietnam Meteorological Hydrological Administration (VMHA) with authority to issue forecasting/warning information for weather, climate, hydrology, water resource, marine weather (i.e. hydro-meteorology) and provide hydro-meteorology services [http://www.nchmf.gov.vn/web/en-US/105/92/Default.aspx accessed on 13.09.2018]. It works with the vision to become ‘the leader in the Southeast Asian region in weather and climate services to save people and society’.

NCHMF works with the following duties and responsibilities:

1. To develop and implement the standardized operational procedures, standards, technical regulations, the quota for economy-technology, projects, programs on hydro-meteorological forecasting.

2. To establish, operate, and exploit the national hydro-meteorological forecasting and warning services; provide the guidance for the provision and usage of hydro-meteorological forecasting information, hydro-meteorological disasters warning.

3. To monitor, summarize and report about national hydro-meteorological condition, hazard and climate change as well as climate change trend in Asia region and over the world.

4. Organizing operational hydro-meteorological forecast activities including:
   a) Forecasting tropical cyclones and tropical depressions; heavy rainfall; cold surge and associated weather such as: very cold weather, frozen, frost; heat wave and very hot weather; thunderstorms, gusty winds, tornadoes, lightening, hail and local heavy rainfall; flood and inundation; flash flood, landslide caused by heavy rain or runoff; drought; saltwater encroachment; high wave and storm surge caused by tropical cyclone and strong monsoon, tide, coastal fog and other hazardous hydro-meteorological phenomena.
   b) Forecasting the risk level for hydro-meteorological related phenomena.
   c) Forecasting 10-day weather conditions on land and over ocean.
d) Forecasting monthly, seasonal meteorological conditions as well as climate condition and the trend of climate change, trend of climatic variations.

e) Forecasting short, medium range and monthly, seasonal hydrological conditions as well as water resources for river basins in Vietnam.

f) Forecasting 10-day, monthly marine conditions as well as sea level trend caused by climate change in coastal areas of Vietnam.

5. Issuing and transmitting the forecast bulletins for meteorology, hydrology, hydro-meteorological related hazard and risk levels in Vietnam

6. Implementing hydro-meteorological forecast for meteorological, hydrological phenomena and hazard as a member of regional and international organizations if assigned by the Administrator of VMHA.

7. Developing the standardized national climate dataset and the National Framework for Climate Services for Vietnam.

8. Developing radio, television programs, websites for meteorological hydrological phenomena and hazard forecast and warning; participating in public education on meteorological, hydrological forecast and warnings.

9. Participating in operational hydro-meteorological forecasting, guide, examine, monitor and technical training for regional and provincial centers; supervising the outside hydro-meteorological forecasting activities including other ministries, local governments and individuals and private companies, if assigned by the Administrator of VMHA.

10. Participating in the process of document verification of the provision, extension, suspension, withdraw the permits of hydro-meteorological forecasting and warning activities as well as weather inducing plan, if requested by the Administrator of VMHA.

11. Conducting research, application and technology transfer of new hydro-meteorological forecasting, if assigned by the Administrator of VMHA.

12. Implementing the international cooperation programs on hydro-meteorological forecasting, if assigned by the Administrator of VMHA.

13. Providing the meteorological, hydrological and marine services for agencies, organizations and individuals.
NCHMF has the role of providing the meteorological background forecast for the entire Vietnam and Bien Dong Sea (the east sea of Vietnam). After receiving the background forecasts, the regional centres or provincial centres will add more detail forecast and warning for areas for which these centres are responsible.

The Main functions of NCHMF are as follows:

1. Formulating annual and long-term strategies, programs, plans related to hydro-meteorological forecasting.
3. Regular monitoring of the hydro-meteorological conditions over the entire country and related areas.
4. Issuing hydro-meteorological forecasts, warnings and advisories as assigned for disaster prevention and preparedness, socio-economic development, and national defence security.
5. Establishing and managing a telecommunication network to meet the requirements of hydro-meteorological forecasting in exchanging and transmitting hydro-meteorological data.
6. Providing consultancy and services on hydro-meteorological forecasting to organizations and private sectors under the current laws.
7. Carrying out researches and applications of new technologies on hydro-meteorological forecasting.
8. Supplying instructions on operational hydro-meteorological forecasting and telecommunication; and validating the implementation of these instructions at Regional and Provincial Hydro-meteorological Centers.
9. Organizing training courses on operational hydro-meteorological forecasting and telecommunication.
10. Accomplishing international cooperation projects and programs on hydro-meteorological forecasting, data transmission and other related issues.

In NCHMF, the operational Numerical Weather Prediction (NWP) web portal system named MHDARS is used to provide the forecasters all NWP related products. There is a web portal for Severe Weather Forecasting Demonstration Project (SWFDP) In Southeast Asia (SWFDP – SeA) of World Meteorological Organisation (WMO). In some aspects, the SWFDP-SeA web portal (http://www.swfdp-sea.com.vn) has some features of the NCHMF web portal but it focuses on the risks of heavy rainfall and strong wind and the confidence level of the risk areas guiding from deterministic/ensemble global and regional Numerical Weather Prediction (NWP) models. NHMS and NCHMF will host this system in coming years, as per the website. Therefore the SWFDP-SeA web portal is like an advanced version of MHDARS for sub centers.
The regional and provincial centres have been accessing the SWFDP-SeA web portal since 2011. 

There are a lot of NWP products from different international centres and at different scales. Therefore the forecasters do not have enough time to look at all of the products. For that case, the risk maps with confidence degree tables are quite useful for forecasters to know the uncertainties of the model forecasts or the high variable weather situations and reducing the possibility of unnecessary focusing too much on only one model. 

There are altogether 27 Surface and upper-air stations (OSCAR/ Surface) as per specific website page of Vietnam of WMO website ([https://www.wmo.int/cpdb/viet-nam](https://www.wmo.int/cpdb/viet-nam)). Details of these stations are given below:

**Table – 17 : Details of Surface and Upper Air Stations in Vietnam**

<table>
<thead>
<tr>
<th>Station Name</th>
<th>Index</th>
<th>Observing remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bach Long VI</td>
<td>48839</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Ca Mau</td>
<td>48914</td>
<td>GOS, CLIMAT(C), RBCN, RBSN(SP)</td>
</tr>
<tr>
<td>Cao Bang</td>
<td>48808</td>
<td>GOS, CLIMAT(C), RBCN, RBSN(S)</td>
</tr>
<tr>
<td>Con Son</td>
<td>48918</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Da Nang</td>
<td>48855</td>
<td>GOS, GSN, CLIMAT(C), RBCN, RBSN(ST)</td>
</tr>
<tr>
<td>Dong Hoi</td>
<td>48848</td>
<td>GOS, CLIMAT(C), RBCN, RBSN(S)</td>
</tr>
<tr>
<td>Ha Dong</td>
<td>48825</td>
<td>GOS, RBCN, RBSN(S)</td>
</tr>
<tr>
<td>Ha Noi</td>
<td>48820</td>
<td>GOS</td>
</tr>
<tr>
<td>Hoang Sa (Pattle)</td>
<td>48860</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Hue</td>
<td>48852</td>
<td>GOS, CLIMAT(C), RBCN, RBSN(S)</td>
</tr>
<tr>
<td>Huyen Tran</td>
<td>48919</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Lang Son</td>
<td>48830</td>
<td>GOS, CLIMAT(C), RBCN, RBSN(S)</td>
</tr>
<tr>
<td>Lao Cai</td>
<td>48803</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Station Name</td>
<td>Index</td>
<td>Observing remarks</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------</td>
<td>------------------------------------</td>
</tr>
<tr>
<td>Nam Dinh</td>
<td>48823</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Nha Be</td>
<td>48894</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Nha Trang</td>
<td>48877</td>
<td>GOS, CLIMAT(C), RBCN, RBSN(S)</td>
</tr>
<tr>
<td>Phan Thiet</td>
<td>48887</td>
<td>GOS, CLIMAT(C), RBCN, RBSN(S)</td>
</tr>
<tr>
<td>Phu Lien</td>
<td>48826</td>
<td>GOS, CLIMAT(C), RBCN, RBSN(S)</td>
</tr>
<tr>
<td>Phu Quoc</td>
<td>48917</td>
<td>GOS, CLIMAT(C), RBSN(S)</td>
</tr>
<tr>
<td>Quy Nhon</td>
<td>48870</td>
<td>GOS, CLIMAT(C), RBCN, RBSN(S)</td>
</tr>
<tr>
<td>Son La</td>
<td>48806</td>
<td>GOS, CLIMAT(C), RBCN, RBSN(S)</td>
</tr>
<tr>
<td>Song Tu Tay (South West Cay)</td>
<td>48892</td>
<td>GOS, RBCN, RBSN(S)</td>
</tr>
<tr>
<td>Tan Son Hoa</td>
<td>48900</td>
<td>GOS</td>
</tr>
<tr>
<td>Thanh Hoa</td>
<td>48840</td>
<td>GOS, CLIMAT(C), RBCN, RBSN(S)</td>
</tr>
<tr>
<td>Tho Chu</td>
<td>48916</td>
<td>GOS, RBSN(S)</td>
</tr>
<tr>
<td>Truong Sa</td>
<td>48920</td>
<td>GOS, RBCN, RBSN(S)</td>
</tr>
<tr>
<td>Vinh</td>
<td>48845</td>
<td>GOS, CLIMAT(C), RBCN, RBSN(S)</td>
</tr>
</tbody>
</table>

As per the WMO site, there are two radar stations in Viet Nam. These are at (1) Dong Ha (Lat 16° 48’ 0” N, Long 107° 5’ 0” E) having ground height of 70 metres and (2) Viet Tri (21° 28’ 0” N, Long 105° 25’ 0” E) having ground height of 200 meters and located near Hanoi. Both the radars are located in North Vietnam.

Going by the locations, these radar stations seem to be of no relevance for LMB. However, data collected and distributed by Highland Regional Hydro-Meteorological Centre (HRHMC) and Southern Regional Hydro- Meteorological Centre (SRHMC) is quite important for the LMB, although these data are not available in the website.

In the website of NCHMF, although there is option of forecasting under Hydrology section in different parts of Vietnam like Southern part etc, it seems not so much effective. Thus, from
the published data and website, it is not clear whether NCHMF carries out any special arrangements for dissemination of meteorological data for LMB itself. But, several reports of MRC clearly indicated that such types of arrangements are there in all four countries, as discussed in the following part.

**Meteorological Stations in LMB in a Comprehensive Manner**

Japan International Cooperation Agency (JICA) and MRC comprehensively reviewed the inventory of the meteorological network in LMB in 2001 with the national line agencies and published that in the study report *Strategic Master Scheme for Hydro-Meteorological Network in the Mekong River Basin* (Anonymous, 2004). The objective of this study was to improve the hydro-meteorological network in the LMB in order to provide timely, sufficient and reliable data and information for water resources management. Although, the primary objective was to ensure water availability in LMB and thereby the focus was on the hydrological stations only, but it also gave enough insight into the available meteorological stations available in LMB at that point of time. As per the report, there were 118 meteorological stations operating in 2001 across LMB as per the following table:

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Observed Parameters</th>
<th>Number of Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cambodia</td>
<td>Lao PDR</td>
</tr>
<tr>
<td>1.</td>
<td>Rainfall</td>
<td>13</td>
</tr>
<tr>
<td>2.</td>
<td>Mean Temperature</td>
<td>13</td>
</tr>
<tr>
<td>3.</td>
<td>Max. Temperature</td>
<td>13</td>
</tr>
<tr>
<td>4.</td>
<td>Min. Temperature</td>
<td>13</td>
</tr>
<tr>
<td>5.</td>
<td>Wind Speed</td>
<td>13</td>
</tr>
<tr>
<td>6.</td>
<td>Wind Direction</td>
<td>13</td>
</tr>
<tr>
<td>7.</td>
<td>Relative Humidity</td>
<td>13</td>
</tr>
<tr>
<td>8.</td>
<td>Evaporation</td>
<td>13</td>
</tr>
<tr>
<td>9.</td>
<td>Sunshine duration</td>
<td>1</td>
</tr>
<tr>
<td>10.</td>
<td>Solar Radiation</td>
<td>1</td>
</tr>
<tr>
<td>11.</td>
<td>Total no. of Stations</td>
<td>13</td>
</tr>
</tbody>
</table>

Since rainfall has a much greater variation than other meteorological parameters, and more rainfall gauges are needed to obtain representative monitoring, many individual rainfall stations were installed over the basin to measure the amount of rainfall in the sub-basins. Total number of rainfall stations in the LMB in 2001 was 449 stations (Cambodia 157 stations, Lao PDR 109 stations, Thailand 110 stations, and Viet Nam 73 stations), both at
meteorological stations and individual stations. Out of these, around 413 stations were operating as on 2014 and the remainder were not (MRC, 2014).

The meteorological data obtained from the member countries are stored in a Master Catalogue (MC) as a time series database. They are available on the MRC data portal as part of MRC Information Systems, which is maintained by the Information and Knowledge Management Programme (IKMP) as a data centre for storing, managing and sharing data and information. Out of the 118 above-mentioned meteorological stations and observed parameters, there are 92 meteorological stations registered in the data portal (MRC, 2014).

Rainfall and evaporation data are available at most stations. Other meteorological parameters are available in only half of the stations. Only 16 stations have solar radiation data. The number of meteorological stations in the MRC dataset (92 stations) is lower than that found in the JICA/MRC inventory review in 2001 (118 stations). Moreover, the location of 21 meteorological stations in the MC is different from the 2001 inventory also (MRC, 2014).

Table – 19 : No. of Meteorological Stations and Observed parameters in the LMB as registered at MRC Data Portal as on 2014

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Observed Parameters</th>
<th>Cambodia</th>
<th>Lao PDR</th>
<th>Thailand</th>
<th>Viet Nam</th>
<th>LMB</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rainfall</td>
<td>24</td>
<td>9</td>
<td>47</td>
<td>12</td>
<td>92</td>
</tr>
<tr>
<td>2</td>
<td>Mean Temperature</td>
<td></td>
<td>7</td>
<td></td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>Max. Temperature</td>
<td>13</td>
<td>7</td>
<td>19</td>
<td>11</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>Min. Temperature</td>
<td>13</td>
<td>7</td>
<td>19</td>
<td>8</td>
<td>38</td>
</tr>
<tr>
<td>5</td>
<td>Wind Speed</td>
<td>14</td>
<td>7</td>
<td>8</td>
<td>11</td>
<td>40</td>
</tr>
<tr>
<td>6</td>
<td>Relative Humidity</td>
<td>13</td>
<td>7</td>
<td>34</td>
<td>11</td>
<td>65</td>
</tr>
<tr>
<td>7</td>
<td>Evaporation</td>
<td>24</td>
<td>8</td>
<td>44</td>
<td>11</td>
<td>89</td>
</tr>
<tr>
<td>8</td>
<td>Sunshine duration</td>
<td>9</td>
<td>7</td>
<td>14</td>
<td>10</td>
<td>45</td>
</tr>
<tr>
<td>9</td>
<td>Solar Radiation</td>
<td>8</td>
<td>8</td>
<td></td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>10</td>
<td>Total no. of Stations</td>
<td>24</td>
<td>9</td>
<td>47</td>
<td>12</td>
<td>92</td>
</tr>
</tbody>
</table>

The current MRC data portal stores rainfall data of the meteorological stations as well as rainfall data of the stand-alone stations. The records of some stations date as far back as
Figure – 17: Locations of the Meteorological Stations in LMB as in 2014 (Source MRC, 2014)
While the records of others are much more recent. A total of 487 rainfall stations contained rainfall data in the MRC data portal: 435 stations were in the LMB (Cambodia 184 stations, Lao PDR 65 stations, Thailand 140 stations and Viet Nam 46 stations); the remaining 52 stations are outside the basin (MRC, 2014). Since 2006, the Flood Management and Mitigation Programme (FMMP) also has been regularly collecting daily rainfall data from the four member countries through the SMS-based HYDMET system to be inputted into the flood forecasting system.

Global Datasets

The global surface summary of day (GSOD) dataset is produced by the National Climatic Data Center, National Oceanic and Atmospheric Administration (https://www7.ncdc.noaa.gov/CDO/cdoselect.cmd?datasetabbv=GSOD&countryabbv&georegionabbv) accessed on 14.09.2018) under the World Meteorological Organization’s (WMO) World Weather Watch Programme as per WMO Resolution no. 40. Data from over 9,000 stations around the world are typically available. The latest daily summary data are normally available 1-2 days after the date/time of the observations used in the daily summaries. This dataset is widely used in the climate change analysis and modelling at the global scale.

Table – 20: No. of Meteorological Stations and Observed parameters in the LMB as GSOD data set as on 2014

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Observed Parameters</th>
<th>Cambodia</th>
<th>Lao PDR</th>
<th>Thailand</th>
<th>Viet Nam</th>
<th>LMB</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Rainfall</td>
<td>6</td>
<td>41</td>
<td>38</td>
<td>15</td>
<td>100</td>
</tr>
<tr>
<td>2.</td>
<td>Mean air Temperature</td>
<td>6</td>
<td>41</td>
<td>38</td>
<td>15</td>
<td>100</td>
</tr>
<tr>
<td>3.</td>
<td>Max. air Temperature</td>
<td>6</td>
<td>41</td>
<td>38</td>
<td>15</td>
<td>100</td>
</tr>
<tr>
<td>4.</td>
<td>Min. air Temperature</td>
<td>6</td>
<td>41</td>
<td>38</td>
<td>15</td>
<td>100</td>
</tr>
<tr>
<td>5.</td>
<td>Mean dew point</td>
<td>6</td>
<td>41</td>
<td>38</td>
<td>15</td>
<td>100</td>
</tr>
<tr>
<td>6.</td>
<td>Mean wind speed</td>
<td>6</td>
<td>41</td>
<td>38</td>
<td>15</td>
<td>100</td>
</tr>
<tr>
<td>7.</td>
<td>Max. Wind speed</td>
<td>6</td>
<td>41</td>
<td>38</td>
<td>15</td>
<td>100</td>
</tr>
<tr>
<td>8.</td>
<td>Total no. of Stations</td>
<td>6</td>
<td>41</td>
<td>38</td>
<td>15</td>
<td>100</td>
</tr>
</tbody>
</table>

There are 100 meteorological stations in the GSOD portal from LMB as in 2014, although the data in the dataset at many stations, particularly in Lao PDR and Cambodia, are not up to date and the records also cover a very short period of time. Around 64 stations have up-to-date data till 2012 (MRC, 2014). Sunshine duration and solar radiation parameters are not included in this data set. All these stations are included in the list of 118 stations as mentioned above and whose locations have been shown in the above figure.
Figure – 18: Locations of the GSOD Meteorological Stations in UMB (Source, MRC, 2014)
MRC also can obtain daily meteorological data in the Upper Mekong Basin (UMB) from the GSOD dataset. Around 20 meteorological stations have long-term data available, particularly on rainfall and temperature. The location of these meteorological stations in the Upper Mekong Basin (UMB) and the surrounding area is presented in the above figure.

Thus, there were considerable number of meteorological stations in LMB and the data set are available with MRC. Since MRC is focussed only with sustainable water utilisation along LMB, that may be the reason for not looking into the aspects of forecasting for other disasters like Cyclones and Typhoons, for which other infrastructures particular Doppler Radar System is essential. Further, one of the major advantages of the GSOD centres along LMB is that anyone can access the dataset, provided the index number of any particular station is known. So, it can be concluded that the basic meteorological dataset along LMB are in the public domain for utilisation of the interested persons.

**Trans-boundary Cooperation and Management**

It has already been described that the Mekong River is the common physical thread between the four countries constituting the Indo-China Region. Economies of these four countries are dependent on the ‘water subsidy’ from the Mekong River over the entire LMB. Over a long period of almost fifty years since 1950, these four countries have been working together to address the challenges of protection and conservation of the rich biodiversity and abundant natural resources of the Mekong River that directly support the livelihoods of more than 65 million people living in LMB (MRC, 2018). The dependence on natural resources and the river water of the Mekong River was so deep rooted that in spite of political differences on many issues and even experiences of bitter war between adjoining countries, the political leadership of these four countries came forward and signed agreement to constitute Mekong River Commission (MRC). MRC was established in April, 1995 based on “The Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin” signed between four riparian countries: Laos, Thailand, Cambodia and Vietnam (MRC, 1995; MRC & JICA, 2004).

The 1995 Mekong Agreement has since provided a platform for ‘Water Diplomacy’ and a legal framework for the four countries to cooperate for better development and management of water resources that could bring them economic benefits simultaneously with protecting the environment. It defines the mission and goals of the organisation, and sets out the roles and responsibilities of its three bodies – the Council, the Joint Committee, and the Secretariat – and the strategic objectives of cooperation.
Through protracted dialogues, discussions, negotiations and also through experiences, the member countries of MRC has come out with five sets of procedural rules and associated technical guidelines on data sharing, water use monitoring, water use cooperation, flow maintenance and water quality (MRC, 2018). The first three establish the process of water cooperation, while the rest set the criteria to assess water conditions. These rules, known as the MRC Procedures, provide a systematic and unified instrument for the implementation of the Mekong Agreement (MRC, 2018).

1. **Procedures for Data and Information Exchange and Sharing (PDIES)** approved in 2001 to operationalise data and information exchange of vital water-related indicators among the four Mekong countries.

2. **Procedures for Water Use Monitoring (PWUM)**, approved in 2003 to establish an effective monitoring system of water use of the Mekong and tributaries by various sectors, including domestic supply, irrigation and hydropower.

3. **Procedures for Notification, Prior Consultation and Agreement (PNPCA)**, approved in 2003 to facilitate the cooperation on water use and development with a set of three specific processes for proposed water infrastructure projects.

4. **Procedures for the Maintenance of Flows on the Mainstream (PMFM)**, approved in 2006 to set out assessment criteria and a process to monitor and maintain adequate water flow in the Mekong and Tonle Sap rivers.

5. **Procedures for Water Quality (PWQ)**, approved in 2011 to strengthen a cooperative framework to monitor and safeguard water quality of the Mekong and Bassac rivers with agreed sets of assessment criteria.

**Procedures for Data and Information Exchange and Sharing (PDIES)**

PDIES is one of the most important pillars of Mekong agreement. It has helped in building a foundation for regional data sharing. Trans-boundary water resources management in the Mekong largely depends on the availability of reliable data and information on various sectors. From fisheries to hydrology to water quality, basin-wide field data are crucial for a better understanding of the basin's conditions and subsequent development. Normally, it is always difficult to obtain data on trans-boundary phenomena, as in most of the cases countries place restrictions on how domestic data would be shared with other countries for national security and other reasons.
To facilitate close collaboration on data exchange, the MRC and its member countries developed the Procedures for Data and Information Exchange and Sharing (PDIES), which provide a framework for the Mekong countries to operationalise regional data sharing for better water resources management. Adopted in November 2001, the PDIES became the first set of rules to support cooperation among the four governments coming together under Mekong Agreement.

PDIES has strengthened the data management within the basin. The PDIES and associated technical guidelines define the scope of regional data management and set out the roles and responsibilities of the MRC and its member countries, and the modalities of data acquisition, storage and dissemination. These rules are designed to strengthen the management of reliable information across borders.

Under the PDIES, the countries are required to collect and share various information such as hydrology, meteorology, topography, irrigation, navigation, flood management, hydropower, environment, socio-economy and tourism, etc. Those data are shared with the MRC Secretariat for consolidation, analysis and public dissemination.

Under PDIES, a number of strong networks for data collection for different kinds of monitoring have been set up. As for example, there are 45 stations for Hydro-meteorological data collection, 139 stations for measurements of Rainfall and water level, 48 stations for water quality, more than 100 stations for fisheries, 41 stations for monitoring of ecological health and 17 stations for sediment monitoring etc (MRC, 2018). Details of some of these stations have already been described above and hence not repeated here.

Over the years, the MRC has accumulated extensive data and information crucial for sustainable management and development of the basin, including both historical data as early as 1900 and real-time data on various water sectors. These data are collected through extended monitoring networks that include 45 automated hydro-meteorological stations, 139 traditional stations for rainfall or water level monitoring, 48 water quality sampling stations, and over 100 fisheries monitoring sites (MRC, 2018).

Data dissemination is a major task of MRC. Under PDIES, MRC makes all vital data accessible to the stake holders as well as country governments. The collected information are disseminated through ‘Data and Information Service Portal’ or simply Data Portal. On the Data Portal, for example, visitors can view daily or weekly water levels etc, which have already been described in detail before.
It is very encouraging to note that presently the Data Portal has more than 700 registered users, including policy makers, practitioners, commercial users, researchers and students, who frequently access the MRC databases (MRC, 2018). In 2017 alone, nearly 40,000 visitors from more than 30 countries accessed the Data Portal, with 685 requests made for specific data.

Separate from these technical databases, a high volume of knowledge products based on data analysis and other communication products about the organisation are available on the MRC’s official website. In addition, the MRC maintains two other information gateways: the MekongInfo (http://www.mekonginfo.org/), a platform to showcase Mekong-related news and knowledge products from external organisations; and the Community Forum (http://community.mrcmekong.org/), a gateway for water practitioners and researchers to communicate and share experiences. A number of ‘Main Forums’ and ‘Other Forums’ are also being maintained in this website. Most interesting part of this website is individual practitioners and researchers of their own even tries to answer queries regarding different problems posted in the website. Water related problems in many areas are regularly communicated to the authorities by posting in the website. Thus, already commendable efforts have been taken by MRC for dissemination of information as also feedback mechanism from the community and in the coming days, more and more avenues may be added to this already existing set up, as indicated in their report.

Procedures for Water Use Monitoring (PWUM) – baseline for water development

In the Mekong Basin, millions of rural people rely on its vast natural resources for their food security and livelihoods, while the governments and investors look for opportunities to capitalise on its potential for economic development and broader poverty reduction with water infrastructure projects such as hydropower, irrigation and flood control. It is therefore important to monitor how the Mekong countries use water resources to ensure the sustainable development of the basin, as data on water use would provide valuable information to support basin planning and management.

MRC and its four Mekong countries have developed a framework to support effective monitoring systems for the use of water resources that might impact the mainstream significantly by adopting Procedures for Water Use Monitoring (PWUM) in November, 2003 along with the Procedures for Notification, Prior Consultation and Agreement (PNPCA). PWUM actually envisages the establishment of a proper water use monitoring system for the Mekong’s mainstream and major tributaries.
The PWUM define the scope of work, the role and responsibility of the MRC bodies and its member countries, and the modality of water use monitoring. Under the PWUM scheme, any use of water resources within the Mekong Basin (intra-basin use) and between the Mekong and another basin (inter-basin diversion) with potential significant impact should be monitored. While the member countries are required to collect and supply monitoring data, the MRC Secretariat is entrusted to consolidate data, prepare reports and make recommendations for better usage.

As per the technical guidelines formulated in the year 2006, four Mekong countries are required to first establish a baseline of current water usage within the existing schemes, and to define a set of indicators to monitor intra-basin water use, including rainfall data, water quality parameters and the type of water use; and another set of indicators for water diversion monitoring such as location of diversion, design specifications and diverted water volume. The guidelines also require a comprehensive water use monitoring system to be set up at the MRC Secretariat for data consolidation and storage. Under this framework, monitoring of inter-basin diversion is required daily in the dry season, and at least weekly during the wet season.

However, limited work regarding the implementation of these decisions at the ground level has been done due to certain difficulties. It is really difficult to record the cumulative impacts of many small water users such as family-scale farmers and to establish a regional water use monitoring system when national legislations on water rights systems, such as licensing and water use report requirements, are absent in member countries.

MRC has supported each member country to conduct a pilot study on water use monitoring – each selecting one river catchment to monitor any of the three types of water use: irrigation, hydropower or domestic use. Cambodia conducted a pilot study at the Pursat River, Lao PDR at the Xedone River, Thailand at the Nam Kam River and Viet Nam at the Srepok River. However, all these pilot studies are yet to be completed.

**Procedures for Notification, Prior Consultation and Agreement (PNPCA) – Regional Cooperation on Water Development**

All four countries of MRC are carrying out full-fledged development for which the Mekong countries have begun building bridges, large-scale irrigation and flood control structures, and hydropower dams along the mainstream and tributaries. These projects would definitely bring economic benefits but at the same time may also cause adverse trans-boundary impacts on the ecosystems and livelihoods of people relying on the rivers.
To find a balance between development and protection, the MRC and its four member countries created the Procedures for Notification, Prior Consultation and Agreement (PNPCA), which has established a regional cooperation mechanism over planned water development. Following PNPCA, any member country proposing a major water infrastructure project on the Mekong River system needs to go through a specific cooperation process to ensure sustainable and equitable water use in the region.

This is actually the major mechanism for ‘Water Diplomacy’ in Indo-China region (MRC, 2018). The technical guidelines under PNPCA specifies three processes for regional cooperation on water development, the determining factors for the application of those processes and the roles and responsibilities of the proposing country, the notified countries and the MRC’s three bodies. Any water development project in the region, which may significantly alter water flow or quality of the Mekong mainstream, needs to undergo one of the three processes: Notification, Prior Consultation or Specific Agreement (MRC, 2018).

- **Notification** – requires a country proposing a project to notify its details to other member countries before it commences the proposed use.
- **Prior Consultation** – involves a six-month process of technical assessment and formal consultations on the proposed project before its implementation by a proposing country.
- **Specific Agreement** – requires a thorough negotiation to achieve a consensus on terms and conditions of the proposed project among all member countries prior to the proposed use of water.

These processes are applied to certain water infrastructure projects, based on three determining factors: river type, season and water use scope.

The processes are designed to facilitate water cooperation among the four countries to optimise the use of water resources for development while minimising potential adverse trans-boundary impacts on the environment and livelihoods of riverine communities. None of the processes are intended to approve or reject a proposed project.

For example, in the prior consultation process, the MRC Secretariat and the notified countries assess potential trans-boundary impacts of a proposed project on various water sectors, including fisheries, hydrology and navigation, and recommend measures to mitigate the potential adverse impacts. If needed, the presiding Joint Committee can extend the six-month period for more consultation. Any unresolved case can be further referred to the MRC Council for resolution.
Since 1995 until the end of June 2018, the MRC has received 59 submissions of water infrastructure projects. Fifty-five were submitted for Notification, four for Prior Consultation. Not a single project, so far, has been referred for Specific Agreement.

Among the 55 Notification cases, 50 are on the tributaries and five are on the mainstream, 80 per cent of which are for hydropower projects, and the rest are for irrigation, flood control and other infrastructural development projects. They include Cambodia’s hydropower project proposed on the Sesan tributary in 2010; Thailand’s 1995 proposal to study a plan to divert water from the Kok and Ing tributaries of the Chao Phraya river basin; and Viet Nam’s large scale irrigation project in the central province of Dak Lak proposed in 2005.

All four Prior Consultation cases concern hydropower projects on the Mekong mainstream within Lao PDR: Xayaburi in the year 2010 (MRC, 2011a); Don Sahong in the year 2013; Pak Beng in the year 2016 and Pak Lay in the year 2018. Three completed the six-month prior consultation with thorough technical assessments and public consultations. In the first two cases of Xayaburi and Don Sahong, no formal resolution was reached at the end of the process. In the third case of Pak Beng, the four countries issued an agreed joint statement calling for the Lao government to make every effort to avoid, minimise, and mitigate potential adverse transboundary impacts on water flow, sediment, fish passage, navigation and socio-economic conditions and requesting the MRC Secretariat to prepare an action plan for the post-consultation process. Prior consultation of Pak Lay is expected to follow after its submission.

These prior consultations are test cases for the MRC’s water diplomacy. The process offers opportunities for the notified countries to sit together and address their concerns over transboundary effects based on scientific analysis and for other interested parties to voice their opinions and suggestions. Thus, PNPCA offers a specific mechanism of ‘water diplomacy’ to achieve balanced and sustainable development of the region.

**Procedures for the Maintenance of Flows on the Mainstream (PMFM)**

Objective of this specific understanding is to keep the river flow healthy in the Mekong and Tonle Sap. This was adopted in the year 2006. The Mekong River’s seasonal flow fluctuations are vital to the basin’s ecosystems and the livelihoods of riparian countries. Without its annual flood pulse or the flood subsidy, fish would not migrate from deep pools to floodplains for spawning. Stored floodwaters support irrigation in the dry season while flood-deposited sediments improve soil fertility. Floods also flush out stagnant and polluted waters. It is essential for the Mekong’s ecosystems and livelihoods to maintain these natural flow patterns, particularly against pressures from intensive water investments and climate change.
These particular phenomena are accepted by the policy makers of all four countries and normal annual flood in Mekong is welcome to these countries.

In response, the MRC and its member countries developed the Procedures for the Maintenance of Flows on the Mainstream (PMFM), which set out a framework for how to maintain minimum or maximum levels of river flow of the Mekong mainstream and reverse flow of Cambodia’s Tonle Sap River, which connects the mainstream and the Tonle Sap Lake. The reverse flow is a unique phenomenon that happens during the flood season where the Tonle Sap River flows backwards and pushes its excess water into the lake, causing its expansion to six times its size. The PMFM define technical criteria to assess adequate levels of water flow in order to safeguard the unique seasonal river flow against water diversions, storage releases from reservoirs and other actions that may significantly affect the mainstream.

There are three major points which specify three types of seasonal flow to be maintained for survival of the natural system, as follows:

- Mekong’s minimum monthly natural flow in the dry season (Dec–May)
- Mekong’s maximum daily peak flow in the flood season (Jul–Oct)
- Tonle Sap’s reverse flow in the wet season (Jun–Nov)

As a result of these guidelines, the member countries are required to (1) monitor daily water flow and (2) assess water flow change for proposed water development plans. As a result, daily observations of water level, discharges etc. are being carried out in number of hydrological stations and published in the website which has already been described in details. If the situations become “unstable” or “severe”, the MRC alerts the countries concerned for necessary actions and provides technical support to mitigate impacts, if required.

Till today, the river flow of both the Mekong and Tonle Sap rivers remain mostly normal and stable throughout the year, except one incident of severe situation. It occurred in early 2010 when the 2009 monsoon ended six weeks earlier than normal and the 2010 monsoon started four weeks later than usual. Severe drought conditions were observed at most of the monitoring stations. An assessment indicated that water control at the cascade of hydropower dams in the upper Mekong may have contributed to the regional drought. The four countries were alerted to take mitigating actions. This is an example how this understanding works.
The PMFM framework also supports better water development planning. When a development plan is proposed, water flow change is predicted by calculating water storage, discharge and release out of the proposal and assessed against the water flow criteria. If the predicted water flow is not acceptable, solutions to mitigate the potential impact are recommended to the proposing country.

This compliance test was used for the hydropower projects of Xayaburi, Don Sahong and Pak Beng in Lao PDR during the prior consultation process, already mentioned at the time of discussion of PNPCA above. The predicted flow levels were all found acceptable, because the water storage capacities are limited due to their run-of-the-river type of dam design and operation. The test has also been applied to basin-wide development scenarios with a cascade of planned development projects. The PMFM have contributed to the standardisation of basin-wide flow assessment.

**Procedures for Water Quality (PWQ) – Safeguarding Water Quality of Mekong**

Poor water quality can threaten the health of people and ecosystems. It is thereby essential to maintain and preserve good quality for water of the Mekong River and all other distributaries and tributaries within this Mekong System. Otherwise it will have a negative impact on the river’s aquatic life, as over 65 million people rely on the lower Mekong’s water resources for food and income.

In response to the need to monitor and safeguard the quality of water throughout LMB, the MRC and its member countries developed the Procedures for Water Quality (PWQ), a cooperative framework that ensures the maintenance of acceptable water quality of the Mekong River and its main tributaries. The PWQ and associated technical guidelines established the assessment criteria for management of the water quality along the entire LMB.

Two different action plans have been worked out to keep the water quality acceptable for human, flora and fauna: (1) water quality monitoring and (2) emergency response. The PWQ calls for four Mekong countries to regularly monitor the water quality throughout the basin and prepare response mechanisms for water pollution emergencies, such as oil spills and toxic wastewater discharges, to protect the river and minimise impacts on its ecology and surrounding communities.

As per the PWQ and its technical guidelines, the locations and frequency of water sampling along various rivers have been worked out, as also the set of assessment criteria and target values of water quality for human health and aquatic life. This routine water quality
monitoring is a continuous process and a part of the basin’s monitoring activities that began in 1985 with a network of sampling stations across the Lower Mekong Basin. However, after the PWQ came into operation, it has been further operationalised.

Details regarding the Water Quality Analysis had already been described earlier. Over the years, the MRC has accumulated real-time datasets of water quality of the Mekong and its tributaries. These data allow the Mekong countries to detect any changes in water quality for preventive or remedial actions, and easily identify transboundary water pollution. The data also offer a useful baseline database to study potential impacts of developments. According to the annual reports, the overall quality of the Mekong’s water has remained good throughout the basin, except some isolated problems in highly populated areas, and no compelling evidence of transboundary pollution has been detected so far (MRC, 2018, MRC, 2018a).

As per PWQ, all four countries need to work out contingency plans to address the water pollution emergencies to respond to transboundary emergency situations and to set up basin-wide mechanisms to coordinate actions. Although there have been no transboundary pollution incidents so far, but the countries are agreeable to work out a strategy for developing basin-wide unified responses to effectively manage disasters.

Since the adoption of the PWQ, the four Mekong countries have negotiated national and regional processes to manage water pollution emergencies, and developed the 2016 technical guidelines for the establishment of an emergency response and management system. The guidelines recognise existing mechanisms for emergency responses to natural disasters under the Association of Southeast Asian Nations (ASEAN), and note that an expansion of the mechanisms is underway to cover human induced disasters such as water pollution. To avoid establishing two parallel emergency responses for the basin, the MRC is seeking to collaborate with the ASEAN to develop standardised regional emergency response mechanisms that would meet national, transboundary and regional needs for water quality disaster control.

Thus, a robust transboundary institutional mechanism has been developed within four Mekong Countries through debates, discussions and negotiations on regular basis as a process of ‘Water diplomacy’ so as to guarantee equitable distribution of safe and pollution-free river water among four countries for conservation of natural resources and biodiversity towards protection of life and livelihood of 65 million people living in LMB. This is definitely a unique experience and may be repeated and implemented in other countries based on objective situation at the ground level.
Summary of the existing Hydro-meteorological system in Mekong Delta in comparison to Sundarbans

From the above discussions and deliberations, it is obvious that Mekong Delta have some significant similarity with the Sundarbans from all aspects, namely regional, physiographic set up, climatic condition, social, cultural, economic, even food habits and so on. Needless to mention that every system has some lacuna and the review regarding Mekong System was carried out not for the purpose of looking into the short falls and lacuna. Instead, the entire approach was to learn from the well designed system so as to get some inputs for building up a robust seamless hydro-meteorological system for Sundarbans. Hence, the above discussion has been summarised from that perspective only. The purpose is to highlight the best practices, as have been adopted in Mekong which may also be replicated in Sundarbans:

- Since there is paucity of data and information regarding Mekong Delta per se, the discussions have been made considering the entire Lower Mekong Basin (LMB), which has been considered as a single physiographic as also surprisingly single ‘administrative’ unit, although distributed in four different countries, having completely different Governmental setup.

- The Mekong River passes through six different countries namely China, Maynamar, Laos PDR, Thailand, Cambodia and Vietnam. Although, these six countries in many occasions are not ‘eye to eye’ with each other and even having hostility in the past as also in the present time, but for the sake of Mekong River, some kind of understanding and agreement has been reached by these countries, which is extremely important and exemplary.

- In many instances, even a super power country having mighty economic and military power does realise the environmental importance and thereby follow the same principles of its neighbour country having relatively weak economy and military power, even without formal institutional mechanism as a result of ‘water diplomacy’ which is a bright example of water diplomacy.

- The entire Mekong Basin has been divided into two parts: Upper Mekong Basin (UMB) and Lower Mekong Basin (LMB) depending on the completely different physiographic and topographic set up; yet the interdependence between UMB and LMB has been well recognised in all six countries, which is a positive achievement.

- Interestingly, UMB makes up 24 percent of total Mekong Basin and contributes only 15 to 20 percent of total water resources of the Mekong River although this 15 to 20 percent of water is extremely important for saving the natural resources including biodiversity and survival of 65 million people of LMB during summer season, pointing to the fact that even small fraction of water in a river is important.
• The major issues in the LMB have been identified as the reasonable and equitable sharing of water resources and the sustainable development of natural resources; Identification of problems is the first step towards finding out solutions of any river system, which has been effectively made in case of Mekong System

• River Mekong has been identified as the common physical thread defining the geographical region by all four LMB countries and also considered as important for their own economy, which is an achievement towards conservation and protection of Mekong System

• Accepting the importance of the Mekong River, four LMB Countries namely Lao PDR, Cambodia, Thailand and Vietnam had agreed through protracted discussions and negotiation to share, utilise, manage and conserve water and related resources of the Mekong to achieve the goals of the Agreement for the Cooperation for the Sustainable Development of the Mekong River Basin and signed a common agreement on 5 April 1995 paving the path for constituting Mekong River Commission(MRC)

• Presently, MRC is looking after measurement and monitoring of different parameters and issues along the entire LMB

• Sediment discharge of Mekong is about 160 million tons per year, almost similar to Ganges-Brahmaputra System; but here sediment has been considered as a natural subsidy for agricultural land towards improving production and the approach of LMB countries is to reap the fruit out of these sediments in a positive manner.

• Contribution of percentage of water from all four countries has been estimated.

• Mekong Delta is created by nine distributaries and interestingly the contribution of flows from individual distributaries have been measured and documented.

• There is an extensive network of canals that has been constructed in the last 300 years along Mekong Delta. The structures comprise 7,000 km of main canals, 4,000 km of secondary canals on-farm systems and more than 20,000 km of protection dykes to prevent early floods, a situation similar to Sundarbans pointing to possibility of replicating similar type of management practices in Sundarbans also.

• Annual Flood has been considered as a natural phenomenon (unless it destroys number of valuable properties) in the LMB since it helps in wiping out polluted water out of the river system and nourishing the agricultural land.

• Warning levels along major tributaries have already been well defined for making early warning system.

• A number of tide gauge stations are there in and around Mekong Delta and these stations are mostly pressure sensor operated and automatic in nature.
• In spite of long war, destruction and devastations, most of these tide stations are having long-term data which can be utilised for climate studies, especially for measurement of sea level rise.

• Considering tide gauge stations are important for planning and management, after Vietnam War was over, a number of such automatic tide gauge stations were built up in South Vietnam even within such war devastated economy indicating the government’s understanding regarding importance of tide gauge stations in development of the country.

• Total number of tide gauge stations in LMB is quite high, although cannot be ascertained since the locations of all these tide stations are not available.

• All tide stations are operated and maintained by the same agency pointing to having possibility of similar datum, although cannot be ascertained due to paucity of data in hand.

• Sediment sampling for Monitoring (suspended, bedload and bed material) at different stations along Mekong River in all four LMB countries has been going on for last ten years for understanding the fluvial geomorphology and climate change

• Suspended Sediment Concentration (SSC) along the Mekong River is also measured in regular intervals at fixed stations.

• Similarly Discharge Measurement at different gauge stations along Mekong River in all four LMB countries has been going on for last ten years to understand any changes in discharge along any of the tributaries as a result of climate forcing.

• Detailed bathymetry surveys on regular basis in selected sites are also being carried out.

• Equipment and instruments for sediment sampling, discharge measurement and bathymetry surveys are being purchased in a common pool and distributed in four countries by MRC.

• Altogether fifty nine hydro-meteorological stations are there along Mekong River and its tributaries which are ‘Near Real Time’ and display the water level in the river with only fifteen minutes lag period.

• Since these stations measure the water level on a continuous basis, so in the tidally affected portion of Mekong River, these water level measuring instruments will act as the tide gauge also.

• Two of these stations are located in UMB in China and Government of China cooperates by sending different hydrological data for these two stations after one hour interval.
• Apart from water level, these stations are also having rain gauges measuring quantity of rain in a seamless manner and disseminating the rainfall data in 15 minutes interval.

• An excellent interactive map and data table are being maintained by MRC for disseminating different data on water level (like water level is at normal or at alarm stage etc) and also rainfall data showing the locations; putting cursors on any of the place marks immediately reveals different data.

• In spite of the fact that these stations are distributed over five countries, including China, MRC can coordinate the station in-charges to publish the data in timely manner.

• Twenty four Flood Forecasting Centres are being maintained on regular basis to disseminate information regarding flood on Real Time basis through ‘Flood Forecasting’ Portal of MRC. Two of these stations are in UMB in China.

• A separate webpage of Regional Flood Management and Mitigation Centre is there to announce any flood related information in a seamless manner.

• Even the water level observed in a specific day is computed with respect to long term basis and displayed graphically for understanding of the common men regarding probability of flood.

• Hydrology of Mekong River especially with respect to its individual catchment area has been well estimated and documented.

• A specific point ‘Kratie’ has been identified as a crucial point over Mekong System where the hydrology and hydrodynamics of Mekong River is getting changed significantly. Such identification helps in designing proper management strategy.

• Water Quality measurements and monitoring is being carried out at 48 permanent monitoring stations, of which 11 are in Lao PDR, 8 in Thailand, 19 in Cambodia and 10 in Viet Nam.

• Out of these 48 sampling stations, 17 are on the mainstream, 5 on the major tributary Bassac River, and the remaining stations are on other tributaries.

• At each stations, twelve physical parameters and six chemical parameters are measured on monthly basis following standardised and uniform techniques and results are compared with respect to a well defined ‘Water Quality Index’.

• An informative map on the water quality monitoring has been presented in the website wherein the locations of the stations are indicated by coloured place marks based on water quality as per the Water Quality Index.

• MRC also provides additional services like monitoring of ‘Water Extent’, Precipitation Measurements in inaccessible areas through Global Satellite Mapping of Precipitation (GSMaP), assessment of drought through ‘Keetch–Byram Drought Index’, monitoring of green cover through Normalize Difference Vegetation Index (NDVI) and Vegetation.
Crop Index (VCI) using remote sensing techniques for monitoring the ecosystem health of the LMB.

- MRC has specific programmes for looking into environmental management and biodiversity conservation along the LMB. A number of research studies have been initiated in this regard.

- Mangroves are there on Mekong Delta, which was destructed due to war and other reasons; however Vietnam Government has initiated several programmes to increase the mangrove coverage through co-ordination between different ministries and departments.

- A number of laws and instruments have been enacted and implemented at grass-root level to increase the mangrove coverage.

- A well defined ‘Basin Development Planning’ for the LMB has been formulated based on the principle of IWRM (Integrated Water Resources Management) for a coordinated or integrated approach to basin planning to secure the equitable use of the Mekong’s water resources.

- Considering the necessity of well coordinated actions along LMB, a number of well defined strategies have been formulated, such as ‘Strategy on Opportunities and Associated Risks’, ‘Strategy on Basin Development’ and ‘Strategy on Basin Management’ etc.

- The strategies, thus defined have been implemented through a well defined ‘Roadmap’ setting out priority actions, timeframes and outcomes etc by designing a “Basin Action Plan’ initially for a period of five years i.e. 2011-2016 and thereafter updated for next five years namely 2016-2020 on a long-term outlook and long-term needs for development.

- All four MRC countries are having their individual designated departments for carrying out Meteorology as also Hydrology covering the individual countries. All the countries are members of WMO since long back.

- Department of Meteorology and Hydrology (DMH) under Ministry of Natural Resources and Environment (MNROE) of Lao PDR is the authorised department for carrying out meteorological survey as dissemination for the entire country.

- A ‘National Early Warning Centre’ (NEWC) is in operation under DMH.

- Although it has considerable equipment and number of hydrological as also meteorological stations, DMH has no declared specific programme for the LMB.

- Department of Meteorology (DOM) under the Ministry of Water Resources and Meteorology (MOWRAM) is the authorised agency for carrying out hydro-meteorological surveys, data collection and monitoring in Cambodia.
• In spite of having sufficient infrastructure and logistic arrangements including Doppler Weather Radar (DWR), it has hardly any declared specific programme focused for LMB

• Thai Meteorological Department (TMD) is perhaps having the best infrastructure and manpower amongst all these four countries.

• It has a Climate Centre dedicated towards carrying out data collection, survey and monitoring for carrying out climate change related studies. The website of Climate centre is also playing the role for capacity building of general people for climate change and related issues.

• In spite of having enormous resources including 24 number of DWR, it has also not mentioned any specific programme for the LMB.

• Department of Water Resources, Thailand also plays a supplementary role with TMD for providing hydro-meteorological services, mostly hydrological related issues.

• National Hydro-meteorological Service of Vietnam is the authorised agency for managing and running the national hydro-meteorological station networks and collection and analysis of hydro-meteorological data.

• National Centre for Hydro-Meteorological Forecasting (NCHMF) is having the authority to issue forecasting/warning information for weather, climate, hydrology, water resource, marine weather (i.e. hydro-meteorology) and provide hydro-meteorology services.

• There is hardly any specific focus for LMB although NCHMF and/or other institutions under National Hydro-meteorological Service of Vietnam is having sufficient infrastructure and manpower

• Interestingly, all four countries are having their websites in their own languages encouraging local people to understand the situation on objective basis.

• However, Meteorological Stations in LMB are being looked after, monitored and data collected and stored by MRC in a comprehensive manner. Altogether, 118 meteorological stations in LMB, out of which 100 GSOD stations, collect and store data for LMB.

• MRC even collects daily meteorological data from 20 GSOD stations in the Upper Mekong Basin (UMB) i.e. belonging to China.

• Trans-boundary Cooperation and Management in LMB has been well formulated, institutionalised and implemented at ground level for about last 25 years or more.

• The 1995 Mekong Agreement has provided a platform for ‘Water Diplomacy’ and a legal framework for the four countries to cooperate for better development and management of water resources.
Through protracted dialogues, discussions, negotiations and also through experiences, the member countries of MRC has come out with five sets of procedural rules and associated technical guidelines on data sharing, water use monitoring, water use cooperation, flow maintenance and water quality.

- Procedures for Data and Information Exchange and Sharing (PDIES) were approved in 2001 to operationalise data and information exchange of vital water-related indicators among the four Mekong countries.

- Procedures for Water Use Monitoring (PWUM) were approved in 2003 to establish an effective monitoring system of water use of the Mekong and its tributaries by various sectors, including domestic supply, irrigation and hydropower.

- Procedures for Notification, Prior Consultation and Agreement (PNPCA) were approved in 2003 to facilitate the cooperation on water use and development with a set of three specific processes for proposed water infrastructure projects.

- Procedures for the Maintenance of Flows on the Mainstream (PMFM) were approved in 2006 to set out assessment criteria and a process to monitor and maintain adequate water flow in the Mekong and Tonle Sap rivers.

- Procedures for Water Quality (PWQ) were approved in 2011 to strengthen a cooperative framework to monitor and safeguard water quality of the Mekong and Bassac rivers with agreed sets of assessment criteria.

- The Trans-boundary agreement and adopted mechanisms may be considered as exemplary for developing an institutional mechanism between neighbouring countries for sharing of information and database for achieving sustainable development and for conserving natural resources including biodiversity.
Bibliography


Anonymous (2007), Country Assessment Report for Vietnam : Strengthening of Hydrometeorological Services in Southeast Asia, Joint report of the World Bank, the United Nations Office for Disaster Risk Reduction (UNISDR), the National Hydrological and Meteorological Services (NHMS) and the World Meteorological Organization (WMO) with financial support from the Global Facility for Disaster Reduction and Recovery (GFDRR)


Mekong River Commission, 2016, Strategic Plan 2016-2020, Office of the Secretariat in Phnom Penh (OSP), 576, National Road, #2, Chak Angre Krom, P.O. Box 623, Phnom Penh, Cambodia, pp 1-162

MRC, 2018, An Introduction to MRC Procedural Rules for Mekong Water Cooperation, MRC Secretariat, 184 Fa Ngoum Road, P.O. Box 6101, Vientiane, Lao PDR, pp 1-20

MRC, 2018a, 2016 Lower Mekong Regional Water Quality Monitoring Report, Mekong River Commission Secretariat, 184 Fa Ngoum Road, P.O. Box 6101, Vientiane, Lao PDR pp 1-37.


Ministry of Natural Resources and Environment, 2016, Climate Change and Sea Level Rise Scenarios for Viet Nam, Ha Noi, pp 1–170


Takagi, Hiroshi; Ty, Tran Van; Thao, Nguyen Danh and Esteban, Miguel, 2015, Ocean Tides and the Influence of Sea-Level Rise on Floods in Urban Areas of the Mekong Delta, Journal of Flood Risk Management, Volume 8, Number 4, pp. 292-300


Thuc Tran and Son Duong Hong, 2012, Tidal Regime along Vietnam coast under impacts of sea level rise, VNU Journal of Science, Earth Sciences, 28 pp 133-139


Tuan, Mai Sy, 2016, Mangrove-related policy and institutional framework in Vietnam presented at Final workshop for MFF -FAO sponsored Project “Income for Coastal Communities for Mangrove Protection” Bangkok, Thailand, December 2016

