CHARACTERISTICS OF THE MEKONG MAINSTREAM FLOOD REGIME

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ABSTRACT

This paper examines the nature of the flood regime of the Mekong mainstream both within temporal and spatial terms, by setting it fully within its historical and geographical context. The results and insights that emerge enable a much more informed picture and knowledge base to be built up and so provide the levels of understanding essential to the successful implementation of flood management and mitigation policies and activities. In the wider context this systematic assembly of knowledge is consistent with the goals of the MRC Strategic Plan 2006-2010, in particular where it addresses issues such as basin-wide impact assessment and the enhancement of the MRC's strategic information and knowledge base.

1. Introduction

Flooding of the Mekong River is a recurrent event. Every year the Lower Mekong Basin (LMB) experiences flooding, which has the potential to adversely affect economic and human activities, often claiming lives and causing damage to important infrastructure, human settlement and essential services. Whilst the regular flood cycle is seen as a source of livelihood, severe floods can have a devastating effect upon regional efforts to improve economic development and reduce poverty. The negative effects of floods regularly counteract efforts for economic development and poverty reduction in various places throughout the LMB. At the same time, it is essential also to keep in mind that flood is an essential contributor to the wealth of biodiversity, abundance of fish and soil fertility.

Over the past four years, each member country of the Mekong River Commission (MRC) has prepared an individual annual flood report to be presented during the Annual Mekong Flood Forum. However, while key information was often provided, unfortunately the usefulness of these reports was still limited by lack of standardization and lack of consolidated overview which hindered a clear understanding of the flood events throughout the LMB. To address this issue, a regional view on the Mekong flood characteristics and their effects is obviously needed. The objectives of this paper are therefore to examine the nature and analysis of floods as well as temporal and spatial nature of the Mekong flood regime.

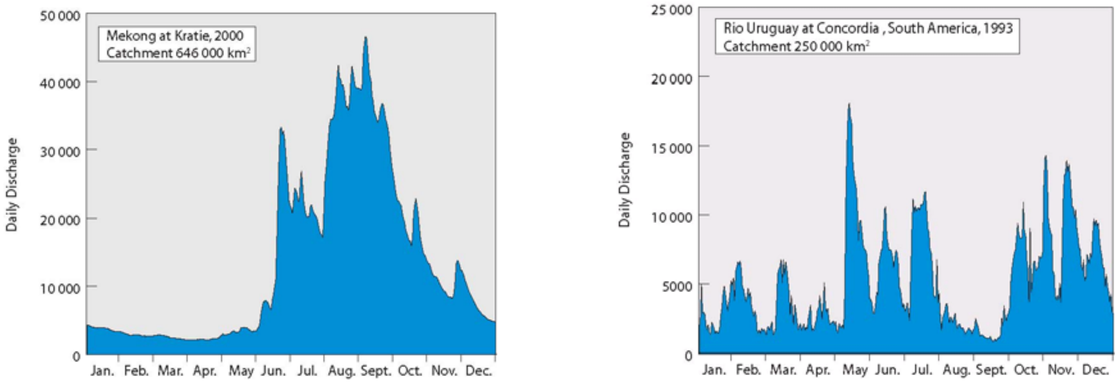
2. Floods in the Mekong Basin

2.1. Flood magnitudes on the Mekong in their global context

Tropical typhoon incursions into the basin from the South China Sea to the east and southeast across Viet Nam and southern China are the weather systems most responsible for generating distinct individual peaks to the monsoonal hydrograph. These generally occur during September and October, when the seasonal discharge is already high and tend to generate a second significant peak to the annual hydrograph. Historically, these events have been responsible for many of the most extreme flood discharges and water levels that have been observed within the Mekong system.

Figure 1. Locations referred to in the text

Figure 1 provides a map of the LMB, which indicates the locations referred to in the text. The highly seasonal and integrated nature of the flood hydrograph is revealed in Figure 2, where a comparison is made between the monsoonal Mekong regime (Figure 2a) and a temperate catchment in South America (Figure 2b). The flood hydrology of the temperate zone river is non-seasonal, with seemingly random flood pulses throughout the year. The convergence and accumulation of monsoonal flood runoff into a single seasonal hydrograph places the Mekong amongst the global river systems, within which the largest meteorological floods have been recorded.



(a) (b)

Figure 2. Comparative hydrological regimes of temperate (a) and monsoonal (b) river systems

2.2. The historical geography of floods on the Mekong mainstream

The geographical distribution of significant flood hazard in the Lower Mekong Basin shows a close link to that of the regional population (Figure 3). Regions of high population density are generally those most exposed to flood inundation. This is consistent with the fact that in tropical regions flood plains provide the most fertile land areas and historically therefore they have witnessed the greatest levels of socio-economic development.

The annual flood regime of the Mekong is not geographically homogeneous in terms of its nature and magnitude from year to year. There is a significant discontinuity evident between the hydrological sub-regions upstream and downstream of Vientiane. Upstream of Vientiane the nature of the flood hydrology in any year is dictated by outflows from Tibet and China—the so called ‘Yunnan Component’ of the overall Mekong regime. Downstream, the large left bank tributaries, particularly, those that lie in Lao PDR (the Nam Ngum, Nam Theun, Se Bang Hieng and the Se Kong) and the Se San and Sre Pok, which enter the mainstream from Cambodia and Viet Nam, progressively mask the Yunnan Component. It is their contribution to the mainstream flow that becomes the foremost influence on the variability of flood season conditions from year to year (Figure 4). Because the incidence, severity and impact of the weather systems that determine the magnitude of the annual flood, such as monsoonal depressions and typhoons, is not necessarily common between these two hydrological sub-regions in any year, there can be significant geographical differences in the annual flood hydrograph.

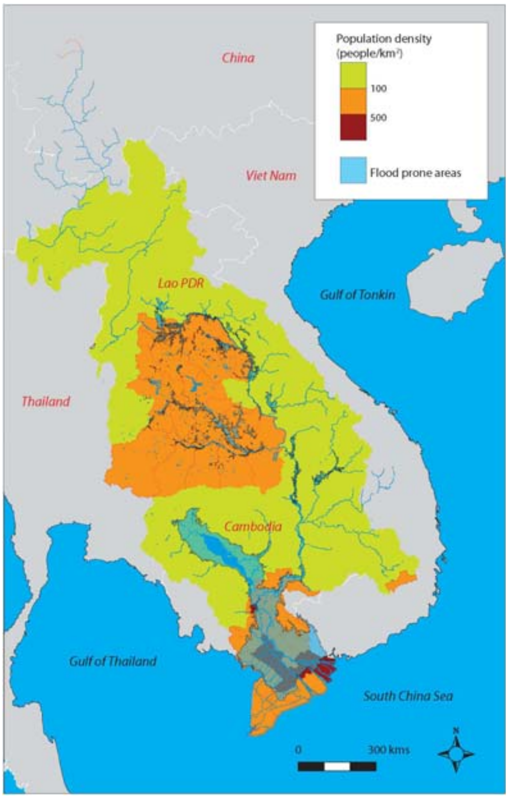


Figure 3. The geography of the flood prone areas in the Lower Mekong Basin compared to the distribution of population

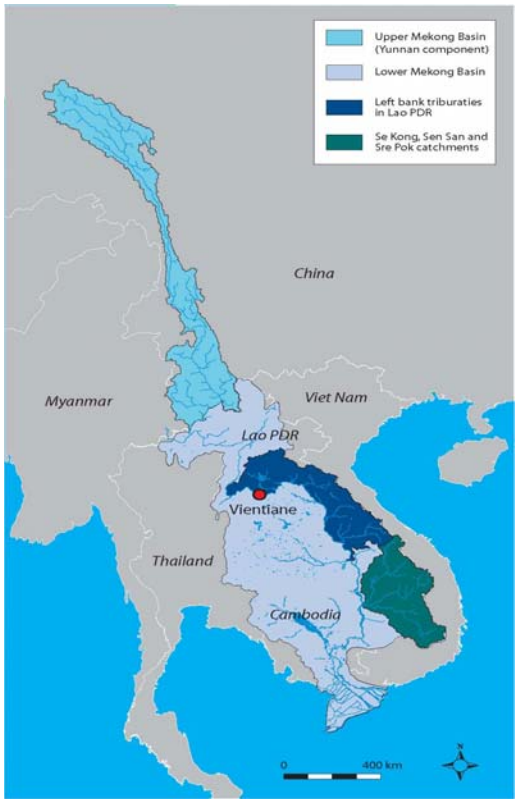


Figure 4. The ‘geography’ of the major hydrological sub-regions that contribute to the spatial non-homogeneity of the flood regime of the Mekong mainstream

In any year the Mekong flood may be above or below ‘normal’ and this departure outside of the ‘normal’ range may be significant or extreme. A basis for an analysis of the historical and geographical variability of the annual flood along these lines is presented in Figure 5.

The distribution of these volumes can be approximated using a Normal Distribution, as shown in the lower plot, and this enables their risk and recurrence intervals to be estimated. ‘Normal’ flood years are defined as those when the flood volume lies within the 1:10 year range, equivalent to a 10% or less annual probability of occurrence. ‘Significant’ flood years are distinguished as those with an annual recurrence interval greater than 10 years and ‘extreme’ years those with an annual recurrence interval greater than 20 years, equivalent to an annual probability of occurrence of 5%. The annual flood volumes above and below the mean are indicated for both Vientiane and Kratie.

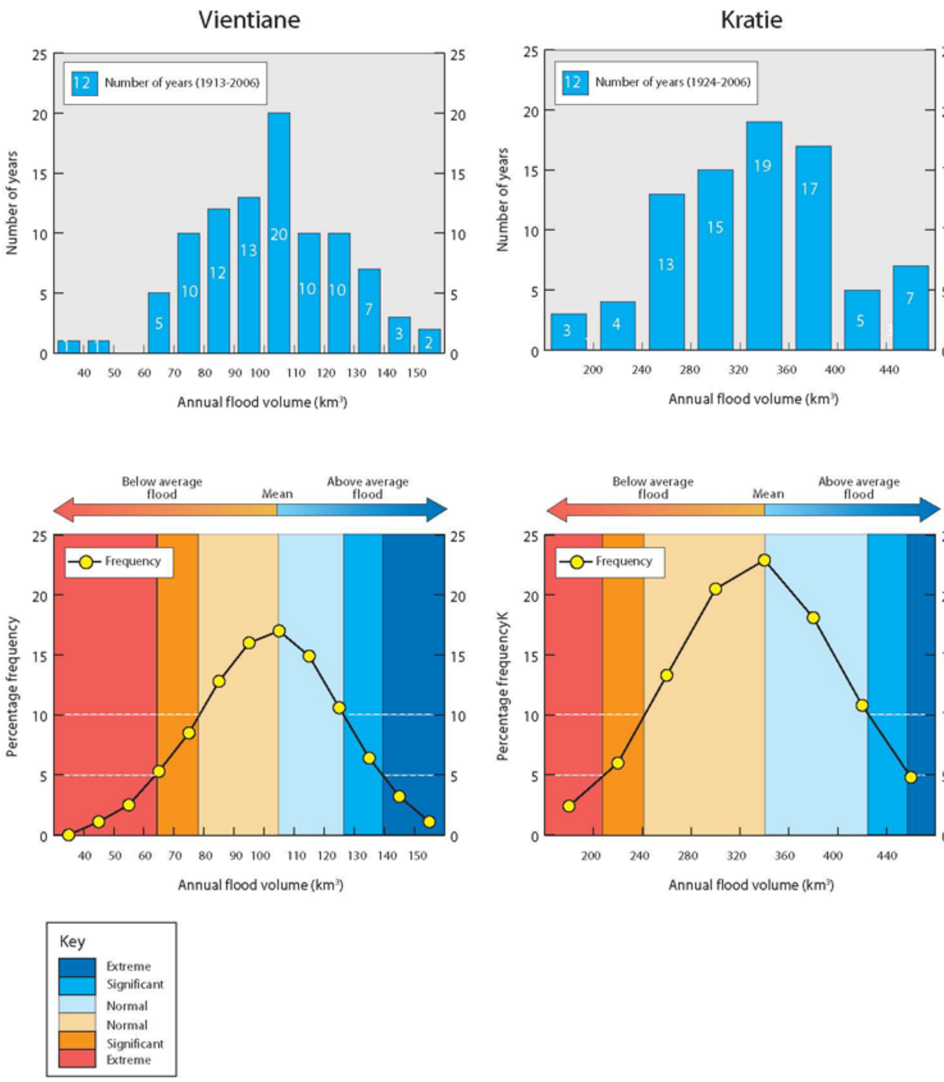


Figure 5. Frequency histograms of the historical distribution of the annual flood volumes on the Mekong mainstream at Vientiane (left) and Kratie (right)

On the basis of this classification, Figure 6 portrays the historical geography of floods along the Mekong mainstream between Chiang Saen and Kratie for the 47 years from 1960 to 2006. The annual flood season flow volumes for each year at ten of the major river gauging locations have been classified as described into ‘significantly’ and ‘extremely’ above and below normal. The result is the flood ‘category matrix’, as shown in the figure:

- The discontinuity up and downstream of Vientiane is clearly distinguishable. This came about because this flood was the result of Typhoon Phyllis which tracked over northern Lao PDR and southern Yunnan, where extreme levels of runoff were generated in late September. Phyllis did not have any significant impacts further towards the south, where flood season volumes were unexceptional. Consequently there was an insufficient further accumulation of the annual flood volume for it to remain classified as severe or significant beyond Khong Chiam.

- Correspondingly, ‘significant’ and ‘severe’ large annual floods can be confined to the hydrological sub-region downstream of Vientiane, as is the case during 2000, 2001 and 2002. This occurs during years when monsoonal depressions and tropical storms generate exceptional volumes of flood runoff within the large left bank tributary catchments, while monsoonal rainfall upstream of Vientiane is less excessive.

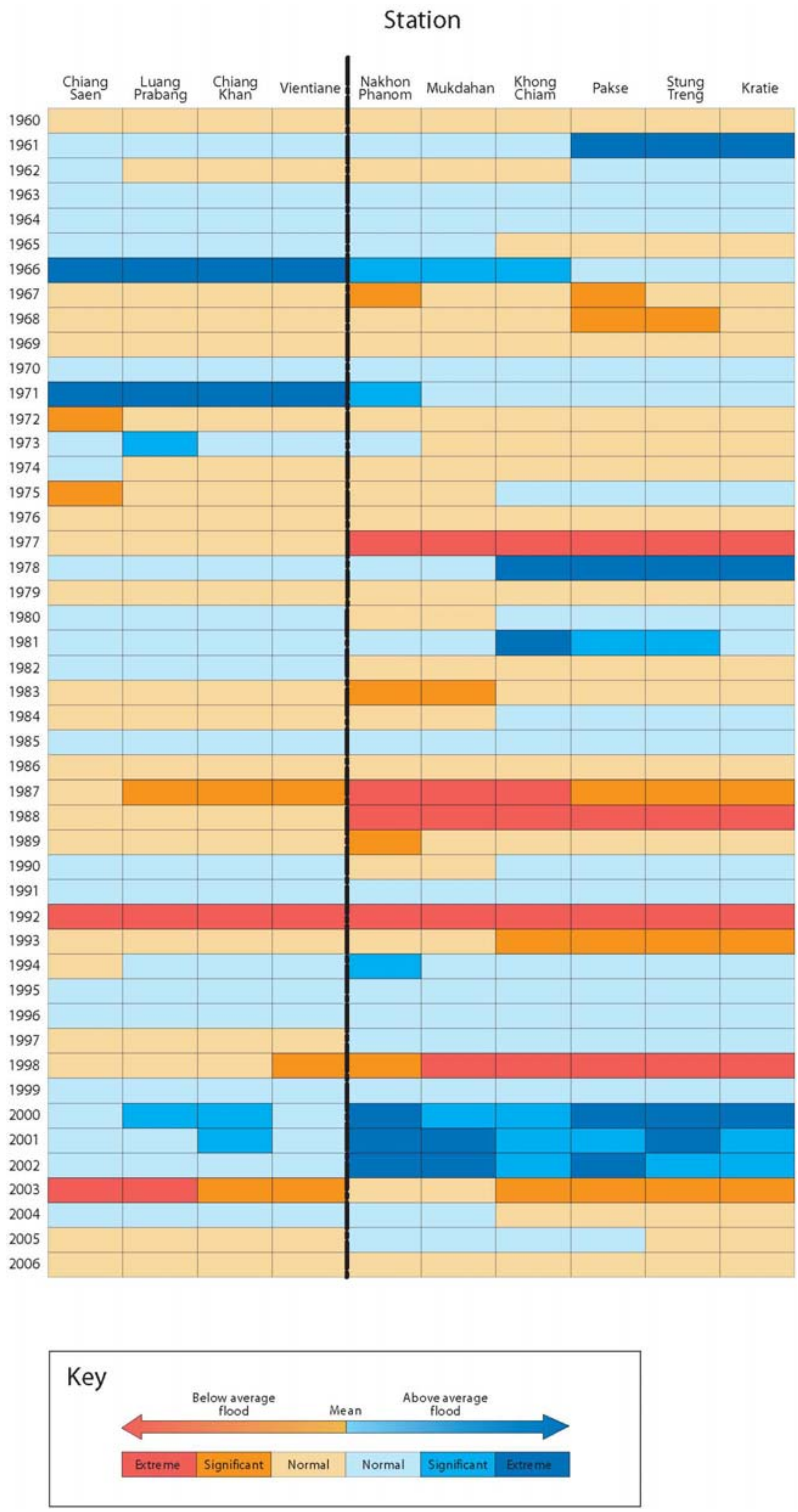


Figure 6. Historical geography of the annual flood regime of the Mekong mainstream (1960–2006)

- In some years, the occurrence of these exceptional flood volumes can be even more confined geographically, for example in 1961 and 1978. This is generally due to tropical storms and typhoons tracking over the far south of the Mekong system only. This was the case in 1978 when Typhoon Joe moved in over these downstream regions and was responsible for the highest annual flood peak recorded at Pakse (56,000 cumecs) and Kratie (77,000 cumecs) over the past 80 or more years. Upstream, in contrast, the 1978 flood season was unremarkable both in terms of peak and volume.

- ‘Significantly’ and ‘extremely’ below average annual flood volumes can also exhibit this same type of geographical non-homogeneity. For example, during 1977, 1988 and 1998 such conditions were largely confined the regions downstream of Vientiane. An exception is 1992 (Figure 7), a year during which daily discharges during the flood season rarely came even close to their long term average and the seasonal flood volume fell to more than 40% below normal. These unprecedented conditions existed throughout the basin.

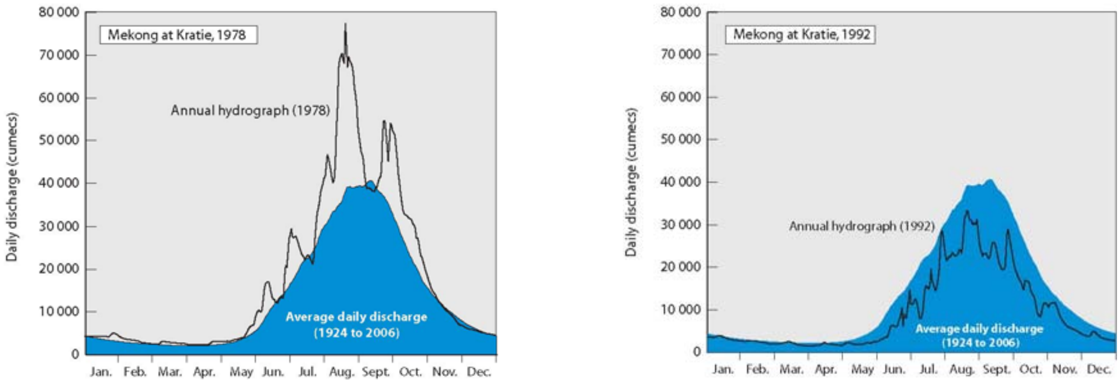


Figure 7. The largest (1978) and smallest (1992) seasonal flood volumes observed within the Mekong system at Kratie over the last 80 plus years

2.3 The nature and analysis of floods on large rivers

A simple but effective way of analyzing the annual Mekong flood is through a scatter plot of the joint distribution of annual flood peak and volume over the period of record, as illustrated in Figure 8. At Kratie, the mean annual flood peak over the 83 years between 1924 and 2006 is 52,000 m^3, and the mean annual flood volume 335 km^3, with standard deviations of 8,300 m^3 and 70 km^3 respectively. Adding and subtracting one and two standard deviations to and from the mean value of each variable prescribes the boxes. One standard deviation away from the mean in either direction encompasses about 70% of the observations. Beyond two standard deviations from the mean only 5% of the observations would be expected to lie and beyond three only 1%.

Such plots readily provide significant insights into the flood history of the Mekong and how events in 2006 fit into the picture:

- At Kratie, the world envelope event of 1939 is surpassed by the ‘reliable estimate’ of 1978, when although the flood volume was similar, the peak discharge was much greater.

- The more recent extreme event of 2000 observed at Kratie killed more than 800 people and resulted in economic damage assessed at more than US$400 million (ADB figures). It was, however, entirely the result of an unprecedented flood volume of almost 480 km3. The flood peak was only marginally above average, with an average recurrence interval of less than five years. Such an observation underscores the point that flood maxima alone are not a satisfactory measure of flood magnitude and therefore of potential flood damage on large rivers such as the Mekong.

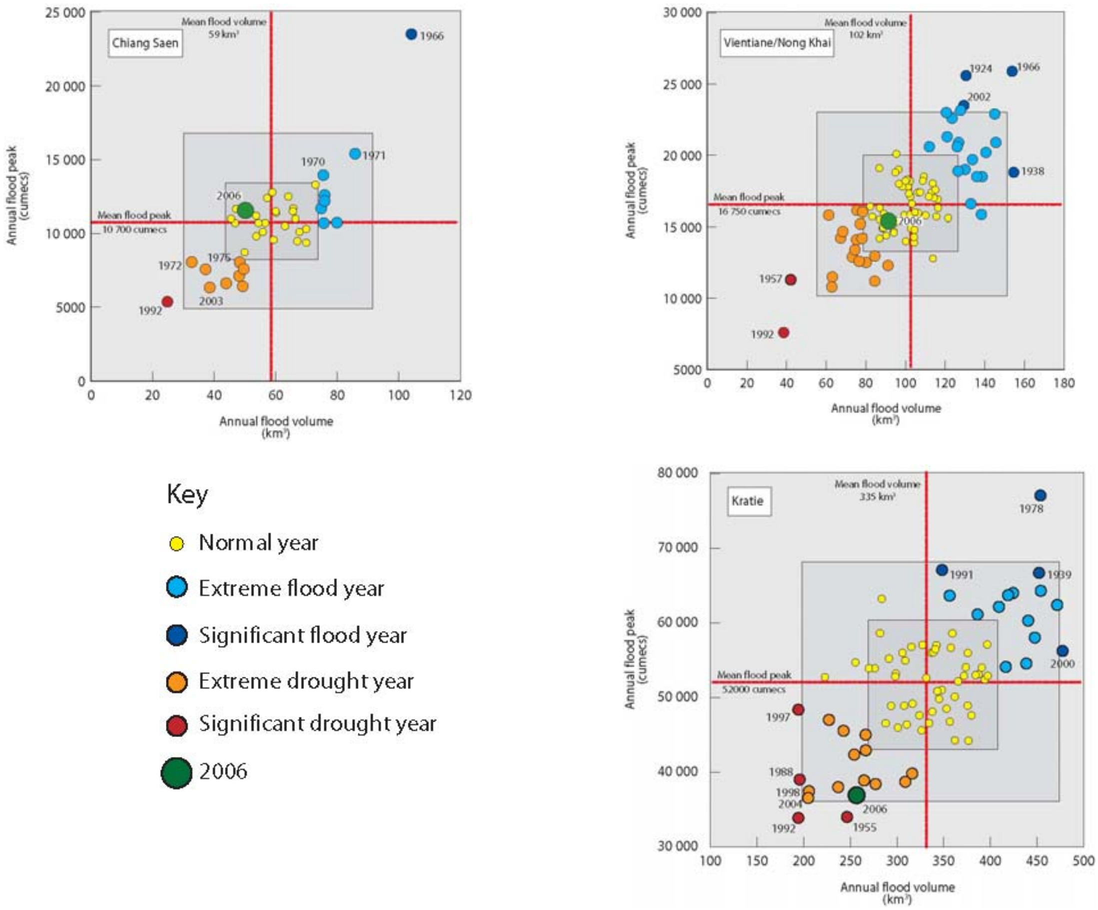


Figure 8. Scatter plots of the joint distribution of the annual maximum flood discharge (m^3) and the volume of the annual flood hydrograph (km^3) at Chiang Saen (1960 – 2006), Vientiane/Nong Khai (1913 – 2006) and at Kratie (1924 – 2006)

- The flood conditions of 2006 at Kratie were significantly below average and in terms of the peak flood discharge, especially low, in fact at an estimated 36,900 cumecs the forth lowest annual maximum since 1924. The 2006 flood season therefore joins the assembly of low peak and low volume flood hydrographs of 1955, 1988, 1992, 1993, 1998 and 2004.

- Upstream, at Vientiane, 2006 flood mainstream conditions were conclusively average. This difference in the conditions between here and Kratie and the fact that, other than the 'driest' season on record (1992), there is little commonality with respect to the classification of the flood seasons from year to year, is a significant aspect of the regional flood hydrology.

- As expected, given this geographical pattern of the mainstream flood regime, the 2006 flood peak and volume further upstream at Chiang Saen were both average and consistent with those at Vientiane in terms of their historical content.

2.4 Temporal aspects of the Mekong flood regime

To analyze the temporal aspect of the Mekong flood regime, an approach is introduced, which provides a definition that extracts meaningful information with respect to the onset and termination of flood conditions, how this timing and duration of 'the flood season' varies from year to year and therefore whether the conditions under specific review are typical or otherwise. An intuitively attractive designation is that period of the year when discharge and water levels exceed their long term annual average.

The four seasons and the measures that define their onset and termination are as follows:

- Transition Season 1: This is a period of the year when the river is not strictly speaking 'in flood' but the dry season has clearly ended. Its onset is defined as the earliest date upon which the discharge rises to twice that of the minimum daily discharge observed in each year (Figure 9). This occurrence confirms the fact that the hydrological response to monsoon rainfall is in progress. The arrival of this fresh seasonal runoff is extremely important biologically, most particularly as a 'cue' to fish migration.

- Flood Season: begins when the flow exceeds the mean annual discharge.

- Transition Season 2: describes a short season between the end of the flood season and the start of the dry. The annual flood has plainly come to a close, but the day to day decreases in discharge are far more rapid than those that are characteristic of the dry season itself. The rate of flow recession at this time of the year has important environmental linkages, for example with the draining of wetlands and the floodplain as well as with the timing of the flow reversal in the Tonle Sap. It is helpful that usually this transition season never extends from one year to the next, historically the latest date for its termination being mid-December.

- Dry Season: The second transition season comes to a close when the average day-to-day decrease in discharge becomes typical of so called baseflow conditions. The rates of flow recession or decrease that signal the start of the dry season were identified (on the basis of some research) as the onset of a rate of decrease in daily flows of 1%, averaged over two weeks. This proved to be a consistent indicator along the mainstream.

The onset dates and duration of these four seasons has been remarkably consistent and unchanged over the last century, and almost certainly over the last 5,000 to 6,000 years. Figure 10 shows a temporal plot of the historical variation of these dates over the last 80 to 90 years at Vientiane and Kratie. Figure 11 sets them within a probabilistic framework.

The timing of the onset and the duration of the seasons is virtually identical at Vientiane and Kratie, despite the fact that the hydrology of the former is dominated by the so called Yunnan component of the overall Mekong regime, while at Kratie the flow regime is largely dictated by flows entering the mainstream from the large left bank tributaries in Lao PDR, downstream of Vientiane. The system is therefore entirely homogenous with regard to these temporal aspects of its hydrology. However, it is not homogenous with respect to the incidence and severity of floods from year to year upstream and downstream of Vientiane.

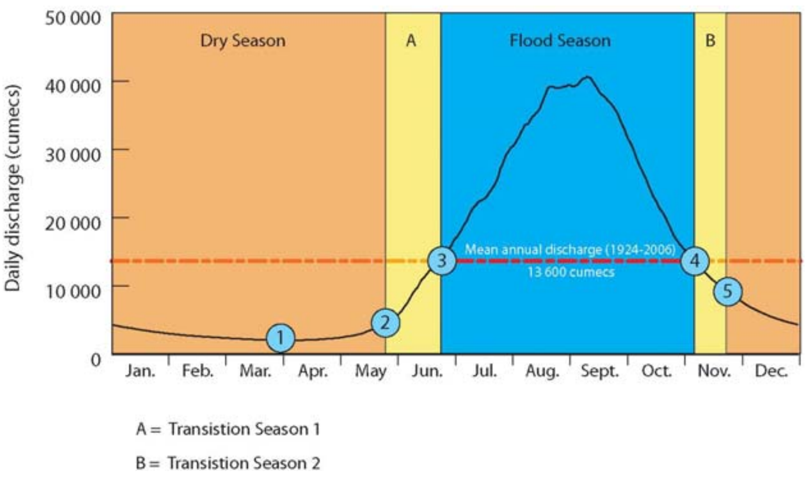


Figure 9. The definition of the onset and closure of the four flow seasons, based on the mean annual hydrograph at Kratie

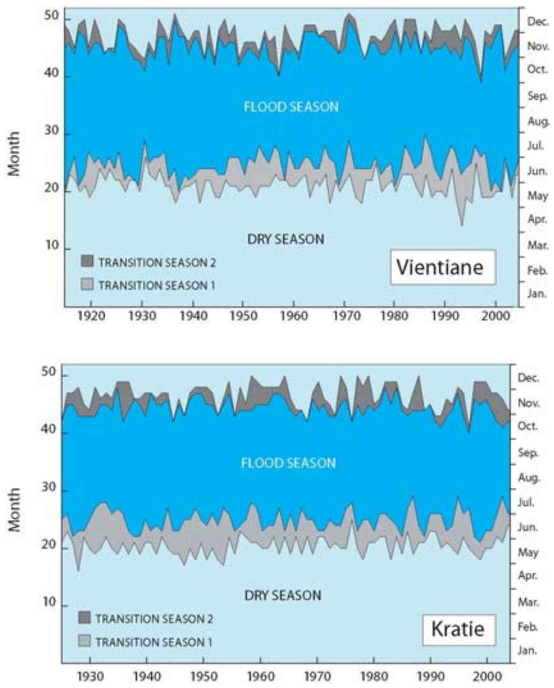


Figure 10. Historical onset and duration of the four flow seasons at Vientiane (1913–2005) and at Kratie (1924–2005)

- The data presented in Figure 10 indicate the probability that a season will start and end before a particular week of the year. For example, at Kratie there is 50% probability in any year that the flood season will begin before week 25 (24th–30th June) and close before week 44 (4th–10th November). More generally, these figures reveal that there is a very narrow 'window' that defines the onset and closure of the seasons.
- The historical mean dates are virtually identical at the two sites. In addition, the very low values of the standard deviations about the means reveal just how predictable these dates are from year to year.

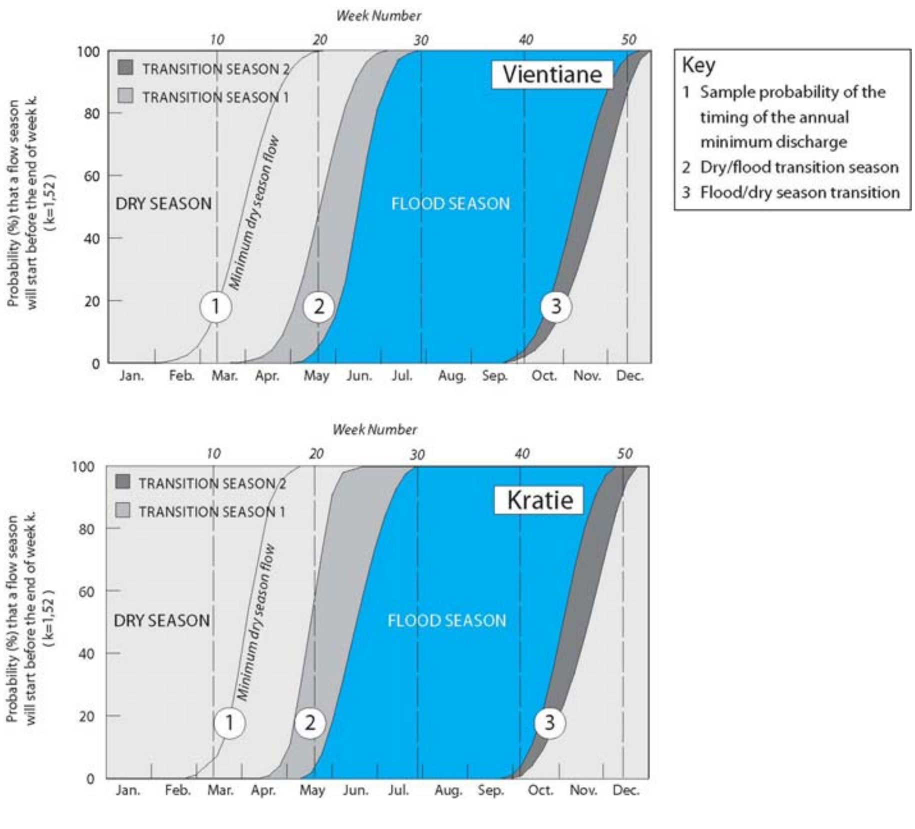


Figure 11. Mekong mainstream at Vientiane (1913–2005) and Kratie (1924–2005)

3. Summary and Conclusion

This paper has examined the temporal and spatial nature of the Mekong flood regime by setting it within its historical and geographical context using appropriate analytical and graphical techniques. The results reveal that the flood hydrograph of the Mekong is a highly seasonal and coherent event, typical of large monsoonal catchment sytems. The close link between the geographical distribution of significant flood hazard in LMB and the distribution of the regional population is noted in addition to the fact that the flood regime is not geographically homogeneous in terms of its pattern and magnitude from year to year. Informative graphical presentations have been developed to indicate significant and extreme departures above and below normal annual flood conditions both in terms of seasonal flood peak and volume. Similarly, the historical geography of the flood regime over the last 45 plus years is presented as a simple but comprehensive summary graphic. Finally, the distinct seasonality of the annual regime is set out within the framework of indices which define the onset and end of four explicit flow seasons from year to year, variables which have wide application in environmental and impact assessment studies.

The results enable deeper insights into the overall structure and pattern of the Mekong mainstream flood regime and provide a fundamental source of information and knowledge for the implementation of meaningful flood management and mitigation policies. They also deliver a valuable contribution to the goals of the MRC Strategic Plan 2006-2010, in particular where it addresses issues such as basinwide impact assessment studies and the enhancement of the MRC's knowledge base.

Acknowledgements

This paper is a part of the 2006 Flood Report of the Mekong River Basin, available as a free download from the MRC's website (http://www.mrcmekong.org). Special thanks are due to the Flood Management and Mitigation Programme team, and international consultant Dr. Peter Adamson and others for their preparation of the report. Thanks are also extended to the National Flood Coordinators of the MRC Member States for their support, guidance and contributions.

Further Reading

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