Hydraulic design conditions for Bokeo river bank protection

Appendix 2 to the Annex 1 to the
Draft Stage 2 Evaluation Report

July 2008

Draft Report

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1 Introduction

The LNMC has selected Bokeo Province along the Mekong River as focal area for river training works to protect the river banks. This includes the following locations along the river (chainage according to hydrographic atlas of MRC):

1. Ban Ton Peung at rkm 2367-2369
2. Ban Don Savan at rkm 2364
3. Ban Kouan at rkm 2359
4. Ban Simouangngam at rkm 2349
5. Ban Bokeo at rkm 2314.

For the design water levels and flow velocities of selected frequencies are required. These data are elaborated in this report.

2 Design water levels

2.1 Requirements

The following water level information is required to support the design:

- MHWL = maximum high water level
- AHWL = 95% not-exceeded water level
- MWL = median water level
- SLWL = 5% not-exceeded water level
- Minimum water level

These water levels for the sections/location defined in Chapter 1 are derived below.

2.2 Computational procedure

2.2.1 Available data

The focal area ranges from rkm 2369 till rkm 2314. This reach of the Mekong is enclosed by the following hydrometric stations:

1. Sop Ruak at rkm 2370.4
2. Chiang Saen at rkm 2364
3. Sop Kok at rkm 2359, and
4. Chiang Kong at rkm 2313.

The location of the stations is presented in Figure 2.1.

Figure 2.1 Location of water level gauging stations around Bokeo

The availability of the water level data is shown in Figure 2.2. It is observed that station Chiang Saen has the longest record starting in April 1960. The records of the other 3 stations start in 1972. These stations have since then been in operation till to date with the exception of station Sop Kok, which record last till 1993. The zero levels of the gauges as available in the Mekong Hydrological Yearbooks are presented in Table 2.1. The development of the zero levels of the gauges appears to have changed in the course of time. These changed references have been taken into account in the transformation of the gauge records into water levels relative to MSL.

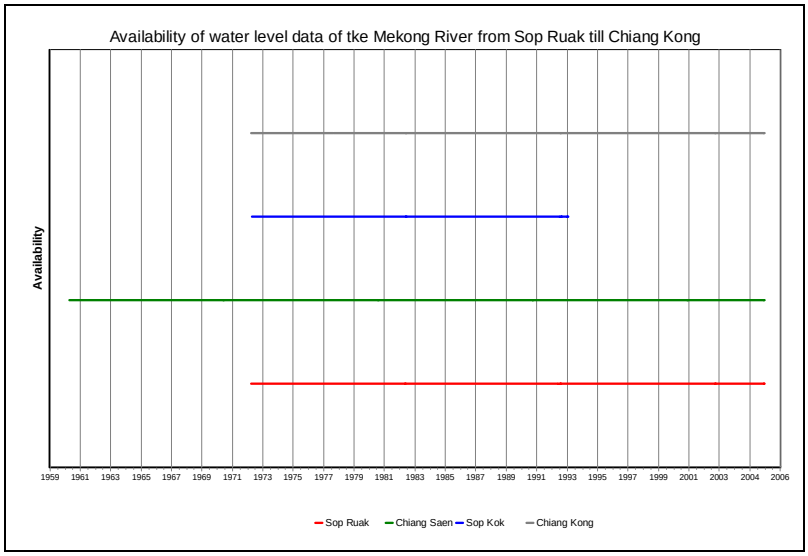

Figure 2.2 Availability of water level data of the Mekong between Sop Ruak and Chiang Kong

Table 2.1 Station ID, chainage and gauge zero levels of water level gauging stations near Bokeo

Station	ID	Rkm	GZ-initially (masl)	GZ-1997 (masl)	Applicable since
Sop Ruak	010401	2,372.4	360.329	359.189	1993
Chiang Saen	010501	2,364.0	357.31	357.11	1994
Sop Kok	010601	2,359.0	355.313	355.313	-
Chiang Khong	010801	2,313.0	341.967	341.963	1993

Cross-sections of Mekong River at the critical locations in Bokeo Province are available from the “Hydrographic Atlas Mekong River in the Lao PDR and Thailand”, April 1996. The bathymetry of the river refers to the situation in 1991/92. The river topography has been reduced to the Lowest Low Water Level taken from a length profile established in 1959/60 by HARZA Corporation from benchmark elevations linked to a third order levelling connected with the Royal Thai survey Department first order levelling originated from Kolak datum.

2.2.2 Water level series

The zero level change in the series of station Sop Ruak listed in Table 2.1 could not be confirmed from a comparison of stage-relations with Chiang Saen. The original series in the analysis has therefore been replaced and extended to the full period 1960-2006 based a synthetic series derived from the stage-relation curve with Chiang Saen based on the years 2002-2006. The stage-relation is shown in Figure 2.3.

The series of Sop Kok has been extended to the period 1960-2006 using the water level record of station Chiang Saen and the stage-relation curve depicted in Figure 2.4.

The frequency curves of the water levels observed at/computed for the stations Sop Ruak, Chiang Saen, Sop Kok and Chiang Khong are presented in the Figure 2.5 to Figure 2.8. Maximum water levels are seen to occur in the months August-September, whereas the minimum water levels are observed in the period March-May. The minimum water levels are gradually increasing due to releases from an increasing number of reservoirs in China.

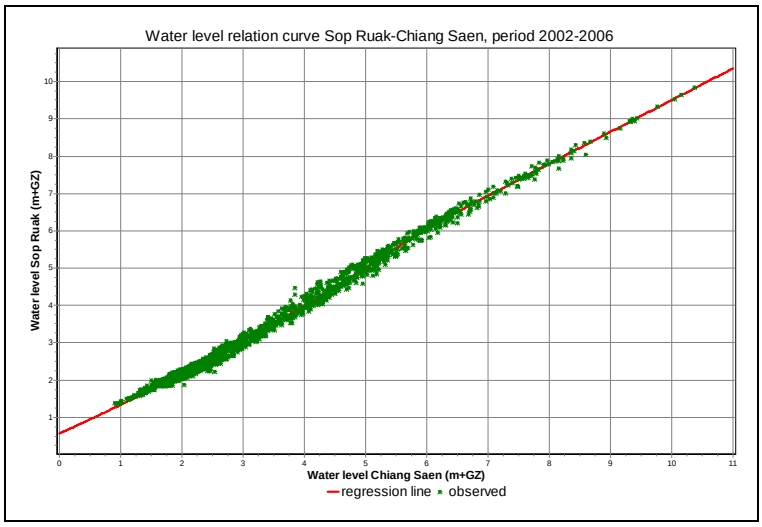

Figure 2.3 Stage-relation curve Sop Ruak-Chiang Saen

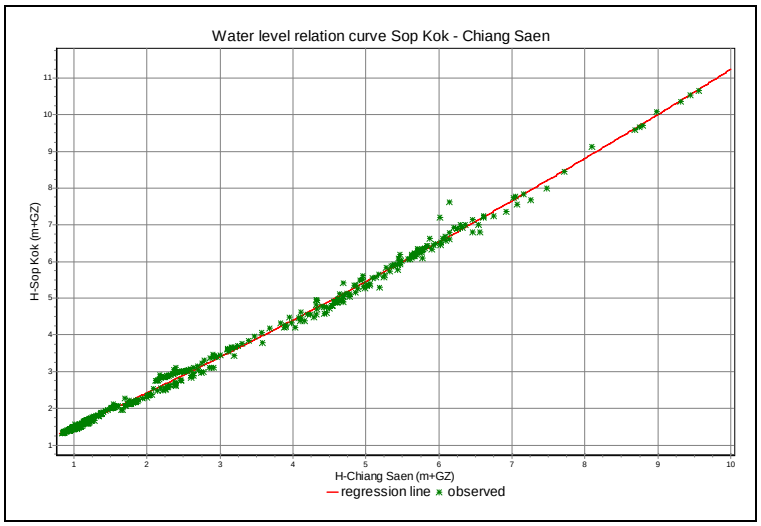

Figure 2.4 Stage-relation curve Sop Kok-Chiang Saen

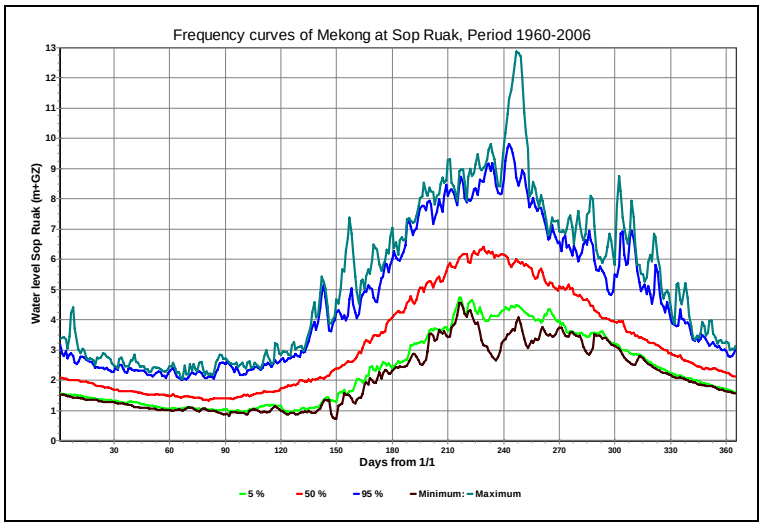

Figure 2.5 Frequency curves of the water level in the Mekong at Sop Ruak, period 1960-2006

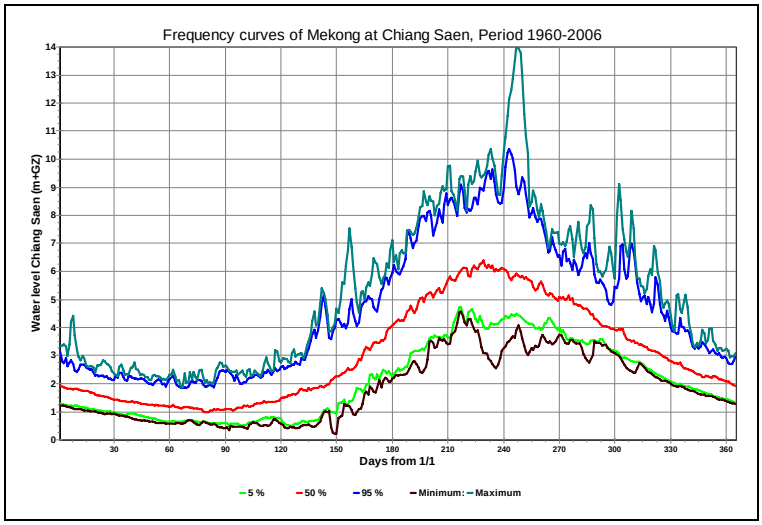

Figure 2.6 Frequency curves of the water level in the Mekong at Chiang Saen, period 1960-2006

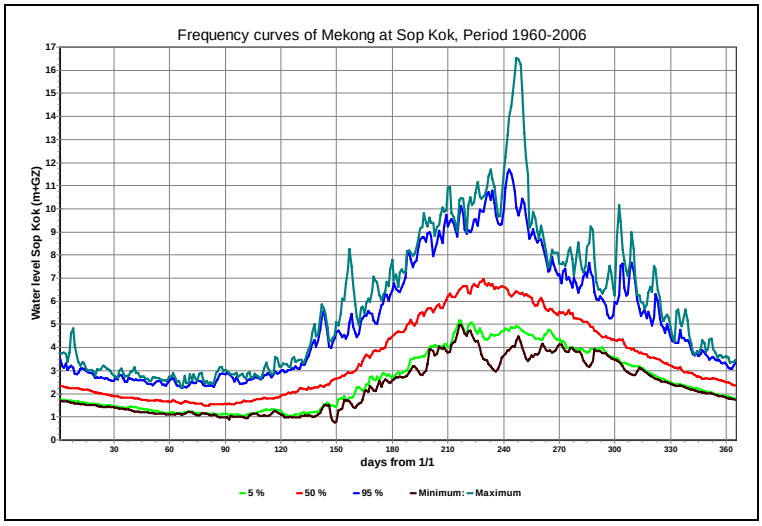

Figure 2.7 Frequency curves of the water level in the Mekong at Sop Kok, period 1960-2006

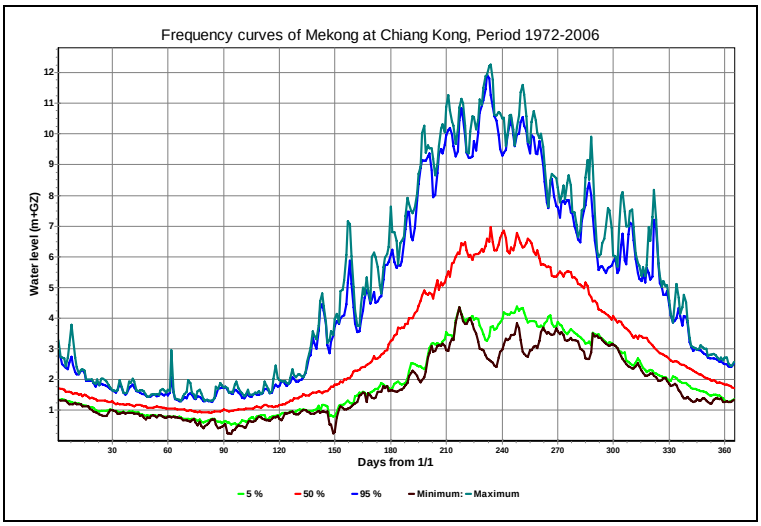

Figure 2.8 Frequency curves of the water level in the Mekong at Chiang Khong, period 1972-2006

The maximum water level curve in the above graphs for Sop Ruak, Chiang Saen and Sop Kok show a large peak in early September. This record high follows from the hydrograph of the year 1966, when an extreme peak flow was observed in the upper part of the Lower Mekong. The return period of the discharge responsible for that peak ranges from 800 years according an EV1 (Gumbel) distribution to 10,000 years based on an GEV-distribution fitted to the observed annual maximum discharge distribution (FMMP-2, 2008).

2.2.3 Design water levels

In view of the exceptionality of the 1966 value for the design of bank protection, in the analysis of observations this unrepresentative extreme high flow year has been eliminated from the record. From the remaining records the following values have been extracted: maximum water level, 95%, 50%, 5% and minimum water level. The average duration curves of the water levels are displayed in Figure 2.9 to Figure 2.12.

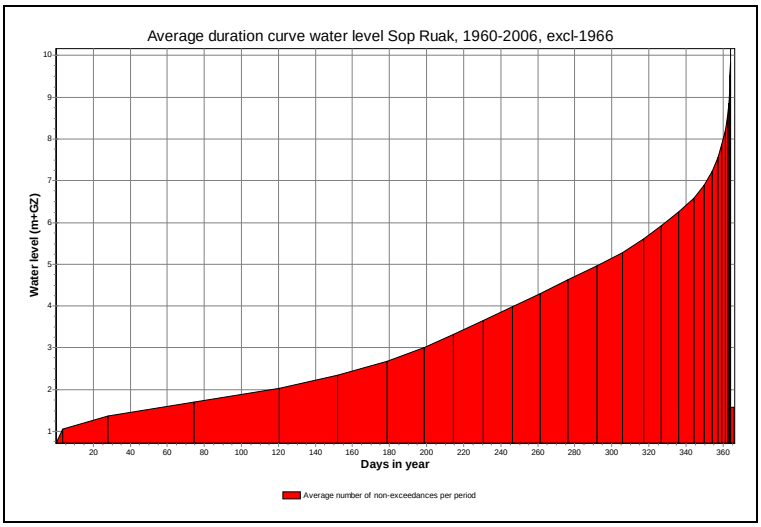

Figure 2.9 Average duration curve of the water level at Sop Ruak

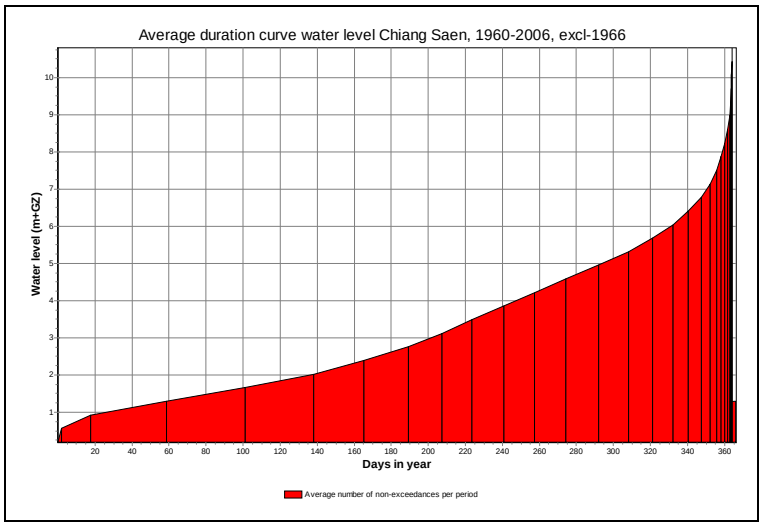

Figure 2.10 Average duration curve of the water level at Chiang Saen

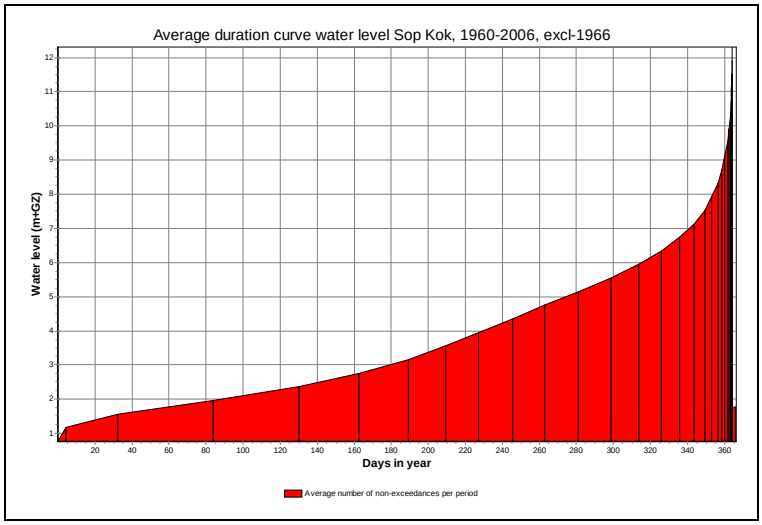

Figure 2.11 Average duration curve of the water level at Sop Kok

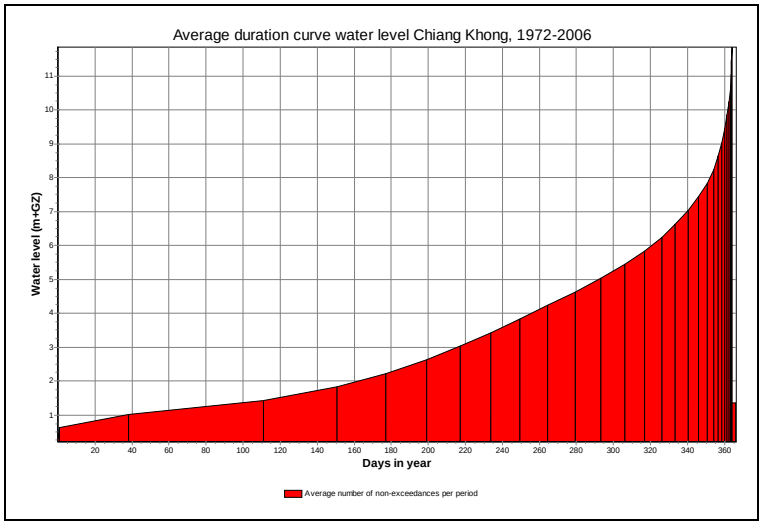

Figure 2.12 Average duration curve of the water level at Chiang Khong

The design water levels derived from these duration curves are presented in Table 2.2. The longitudinal water level profiles in the Bokeo area following from these levels are displayed in Figure 2.13. In this figure also the survey reference in the hydrographic atlas (reference to Sub-section 2.2.1) is displayed, see also Table 2.3. It is observed that this level, apart from the reach Sop Ruak-Chiang Saen, is below the minimum water level as obtained from the gauge record. This may be due to inaccuracies in the Harza reference level, which has been developed before three out of four gauging stations were established.

Table 2.2 Design water levels at location of gauging stations

Location	Min (masl)	5% (masl)	50% (masl)	95% (masl)	Max (masl)
2370.4	360.12	360.64	362.13	366.14	369.89
2364.0	357.31	358.04	359.77	363.86	368.27
2359.0	356.08	356.68	358.37	362.69	368.02
2313.0	342.18	342.77	344.29	349.51	355.53

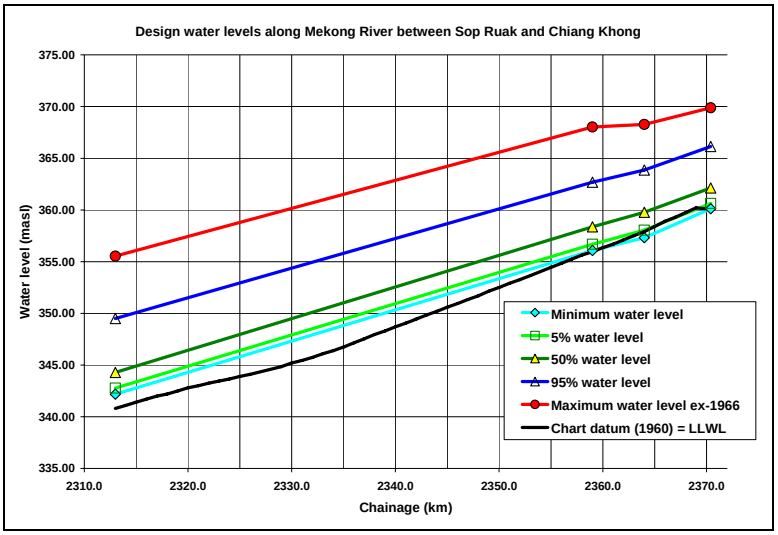

Figure 2.13 Design water levels in Bokeo Province on Mekong River

Table 2.3 Lowest Low Water Level used in survey of Mekong River

Chainage	LLWL	Chainage	LLWL	Chainage	LLWL
2370	360.10	2350	352.50	2330	345.20
2369	360.20	2349	352.15	2329	344.85
2368	359.75	2348	351.70	2328	344.60
2367	359.30	2347	351.35	2327	344.35
2366	358.90	2346	350.95	2326	344.10
2365	358.40	2345	350.60	2325	343.90
2364	357.90	2344	350.20	2324	343.65
2363	357.53	2343	349.85	2323	343.45
2362	357.10	2342	349.45	2322	343.25
2361	356.70	2341	349.05	2321	343.00
2360	356.35	2340	348.70	2320	342.80
2359	355.95	2339	348.30	2319	342.50
2358	355.65	2338	347.95	2318	342.20
2357	355.25	2337	347.55	2317	342.00
2356	354.85	2336	347.15	2316	341.70
2355	354.45	2335	346.75	2315	341.40
2354	354.05	2334	346.40	2314	341.10
2353	353.65	2333	346.10	2313	340.80
2352	353.25	2332	345.75		
2351	352.90	2331	345.45		

The design levels at the bank protection sites have been derived from the levels at the four gauging stations by linear interpolation. The results are summarized in Table 2.4.

Table 2.4 Design water levels for bank protection section in Bokeo

Rkm	LLWL (masl)	Min (masl)	5%-level (masl	50%-level (masl)	95%-level (masl)	Max (masl)
2369	360.20	359.51	360.07	361.61	365.64	369.54
2368	358.75	359.07	359.67	361.25	365.29	369.28
2367	359.30	358.63	359.26	360.88	364.93	369.03
2364	357.90	357.31	358.04	359.77	363.86	368.27
2359	355.95	356.08	356.68	358.37	362.69	368.02
2349	352.15	353.06	353.66	355.31	359.83	365.31
2314	341.10	342.49	343.08	344.60	349.80	355.80

The rates of rise and of fall of the water level at Chiang Saen in m/day are presented in Figure 2.14. Rises up to about 2 m/day are observed , with slightly lower values for the fall.

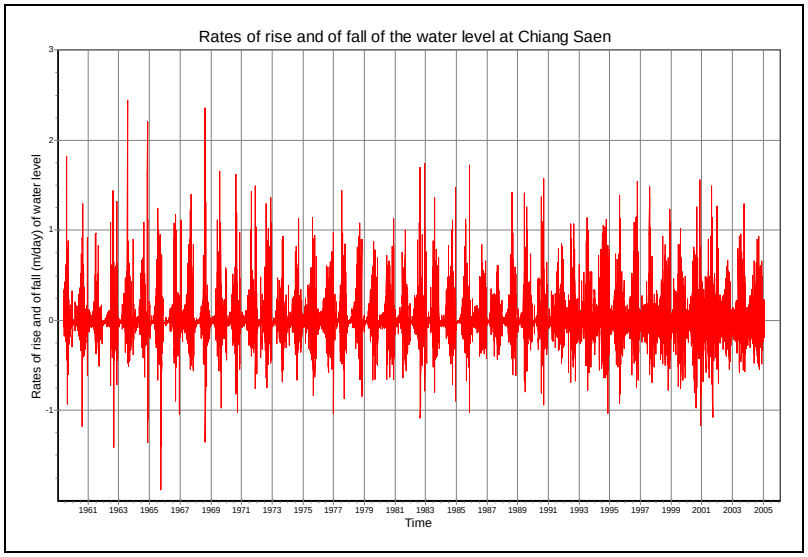

Figure 2.14 Rate of rise and of fall of the water table in Chiang Saen

2.2.4 Flow velocities

For design of river bank protection works and estimation of erosion rates detailed information on flow velocity field is required. This calls for the availability of 2D or 3D hydraulic models of the river stretches. Such models are not available for this reach.

However, for a first inventory an indicative figure as an average flow velocity at maximum water level is considered sufficient. In Table 2.5 the discharge at the maximum water level (excluding 1966) is given. For the reach Sop Ruak-Sop Kok (u/s Nam Mae Kok mouth) this is based on the flow at Chiang Saen. In the reach Sop Kok-Chiang Kong the discharge is derived from Chiang Saen, augmented with the estimated flow from Nam Mae Kok and Nam Mae Ing. The maximum water level refers to the water level in the Mekong on 30 August 1971. The water level for that date at Chiang Kong (yet to be established) has been estimated by extrapolation from a linear stage-relation for high levels between Chiang Khong and Chiang Saen, established for the period 2002-2006.

Table 2.5 Design water levels for bank protection section in Bokeo

Rkm	LLWL (masl)	Max (masl)	Q_{max} (m^3/s)	A (m^2)	v (m/s)
2369	360.20	369.54	15,400	7,570	2.03
2368	358.75	369.28	15,400	8,488	1.81
2367	359.30	369.03	15,400	6,325	2.44
2364	357.90	368.27	15,400	7,930	1.94
2359	355.95	368.02	15,400	9,029	1.71
2349	352.15	365.31	17,100	8,443	2.03
2314	341.10	355.80	17,100	10,097	1.70

2.2.5 Cross-section at design locations

The cross-sections for the required locations with maximum water level are presented in Table 2.6 and Table 2.7 and graphically in Figure 2.15 to Figure 2.21. From the maximum discharge and the cross-sections the average flow velocity is derived (see Sub-section 2.2.4).

Table 2.6 Characteristic cross-sections at river bank protection locations

Rkm 2369		**Rkm 2368**		**Rkm 2367**		**Rkm 2364**	
Distance	**Elevation**	**Distance**	**Elevation**	**Distance**	**Elevation**	**Distance**	**Elevation**
0	370.00	0	375.00	0	370.00	0	370.00
180	360.20	40	365.00	20	365.00	40	355.90
200	359.20	100	358.95	540	359.30	180	357.20
240	358.00	160	359.45	580	358.30	320	355.80
320	359.20	180	358.75	600	356.30	380	356.00
600	360.00	240	358.65	700	355.30	440	356.80
620	370.00	300	358.75	740	356.30	520	360.00
630	372.00	340	358.95	750	358.30	1040	370.00
800	370.00	420	359.25	760	365.00		
820	360.20	480	359.55	770	370.00		
1060	360.20	500	358.75				
1062	370.00	540	358.45				
		620	357.75				
		720	356.95				
		760	358.75				
		840	360.00				
		860	375.00				

Table 2.7 Characteristic cross-sections at river bank protection locations

Rkm 2359		**Rkm 2349**		**Rkm 2314**	
Distance	**Elevation**	**Distance**	**Elevation**	**Distance**	**Elevation**
0	370.00	0	370.00	0	360.00
200	360.00	60	365.00	200	350.00
300	354.55	120	352.15	220	341.10
400	353.55	300	351.15	260	340.10
500	354.65	400	348.15	280	339.10
600	354.55	500	351.15	380	334.10
700	355.45	560	352.15	420	339.10
820	355.95	800	365.00	500	340.10
860	370.00	840	370.00	760	341.10
				820	360.00

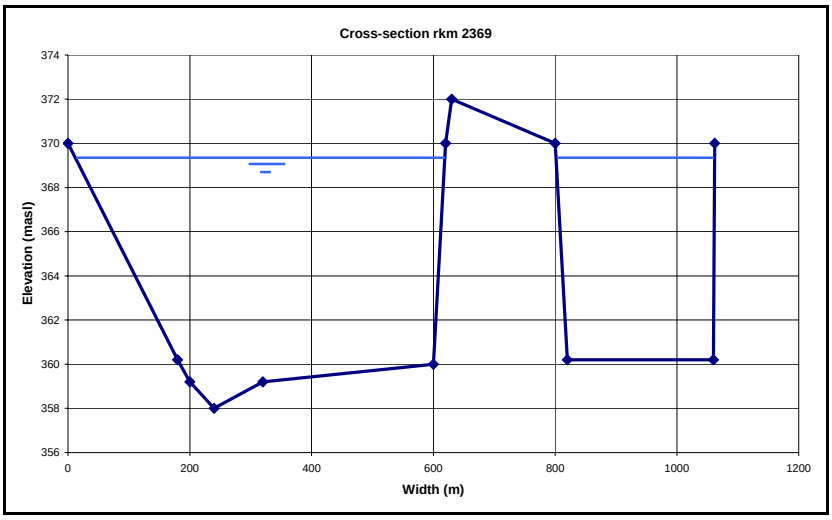

Figure 2.15 Cross-section of Mekong at rkm 2369

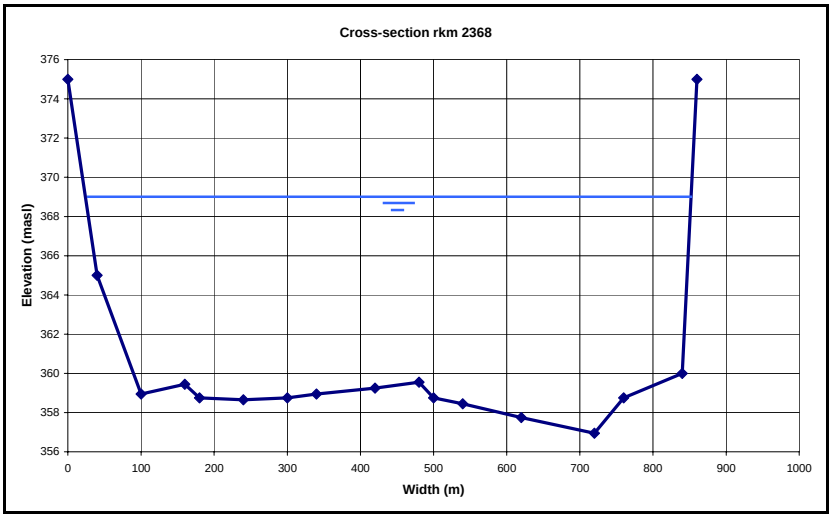

Figure 2.16 Cross-section of Mekong at rkm 2368

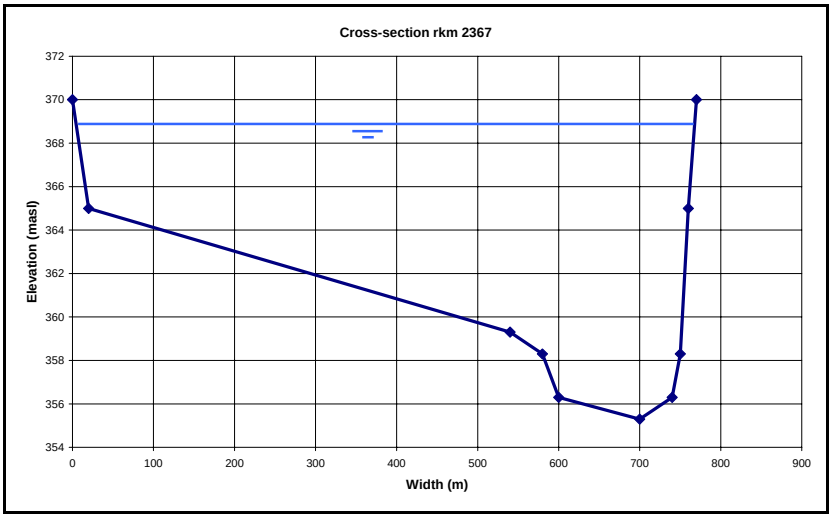

Figure 2.17 Cross-section of Mekong at rkm 2367

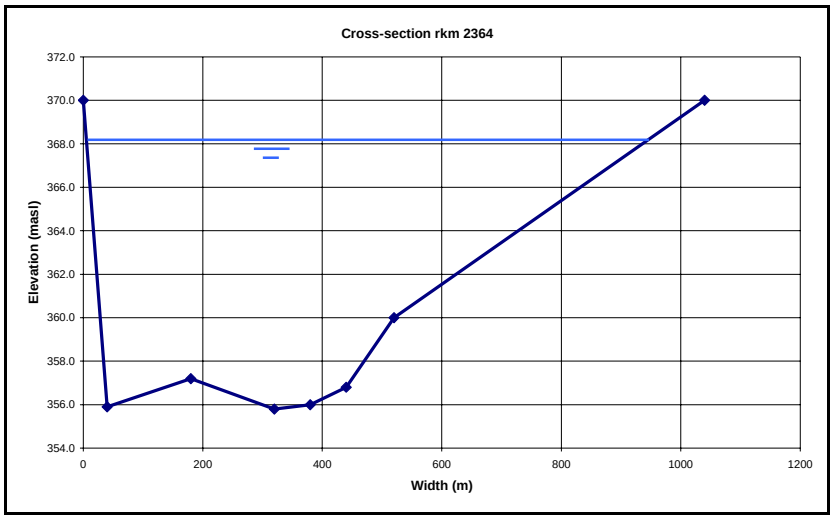

Figure 2.18 Cross-section of Mekong at rkm 2364

Figure 2.19 Cross-section of Mekong at rkm 2359

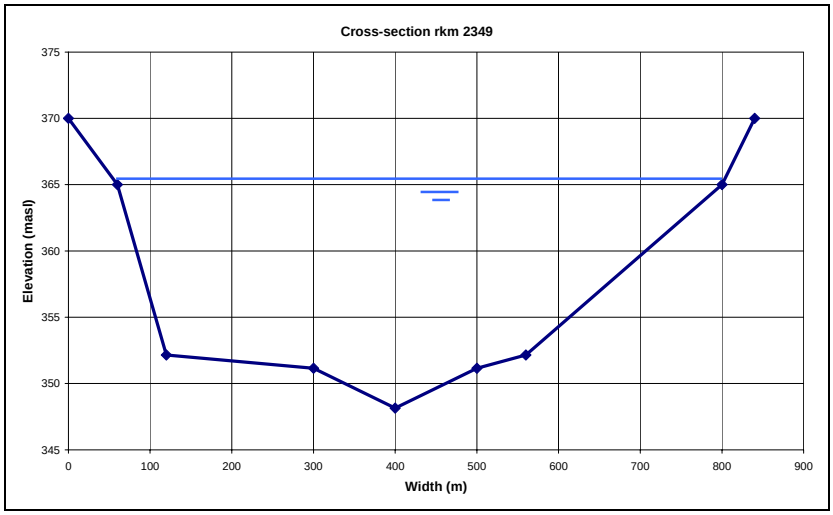

Figure 2.20 Cross-section of Mekong at rkm 2349

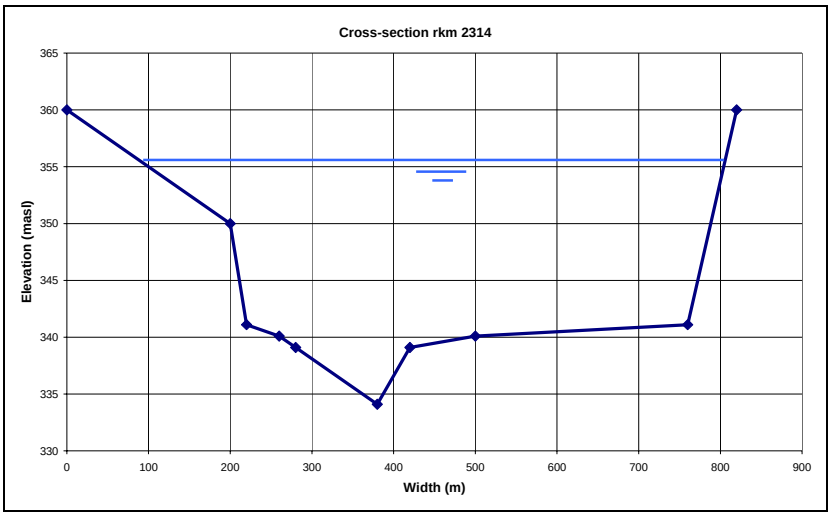

Figure 2.21 Cross-section of Mekong at rkm 2314

3 Literature

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Appendix 1 to Annex 1 Flood hazard assessment Focal Areas
Royal Haskong, Deltares and IHE, July 2008.

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