3. Hydrological Condition of West Baray

3.1 General

Previously the Angkor community had three main reservoirs: North Baray, East Baray and the West Baray. West Baray is the only reservoir still in use. It was constructed by Suryavarman-I in the 11th century for the purpose of irrigation, drinking, bathing and water feeding for cattle. It is approximately 8 km long from east to west and 2 km wide from north to south. The reservoir is currently used exclusively as an irrigation water source.

It is a commonly accepted view that the current inner land accounting for one-third of its original area has been formed by the sediment from the Siem Reap River through the connecting canal. However, the terrain of the reservoir shows similar gradient with that of outside the reservoir. Besides, the Hungarian Study, 1993 has already thrown a doubt on the common view based on the available silting data. This common view must be handled with the utmost care.

3.2 Datum Level

As already reported in several previous studies, it is known that the elevation above the mean sea level are less by about 6 m than that of the local system applied for the reservoir water level. Therefore, it is necessary to pay attention to the description on the reservoir water level.

The water level on March 22, 1997 is 17.70 m, MSL according to the bathometric survey result conducted by the Study Team. On the other hand, the level reading at the same date is 23.11 m according to the readings by the Study Team (refer to Table 2.3.4). The difference is approximately 5.4 m and accordingly the relationship between two systems are presented as follows:

EL (reading) - 5.4 m = EL (MSL)

Present maximum level of 25.0 m equals to approximately 19.6 m, MSL. This relationship is judged reasonable from various water balance reviews conducted in succeeding sections and the point elevation on topographic map at the eastern inner land.

3.3 Height, Area and Volume of Reservoir

The bathometric survey of the reservoir was conducted by the Study Team in March 1997 and the contour map was prepared by using the survey result as shown in Figure 3.3.1. The height, area and volume curve of the reservoir was prepared as shown in Figure 3.3.2 based on the contour. The effective capacity is estimated 48.6 million m^3 at present standard level of 25.0 m (approx. 19.6 m, MSL). The dead storage below the outlet gate is estimated only around 0.2 million m^3, no accurate dimension of the outlet structure is available, though.

3.4 Daily Water Level

The daily water level of the reservoir is one of the most important hydrological data in the Study Area in order to investigate reservoir water balance. The level has been measured daily (at 7:00 AM) by the Hydrology Office since October 1992 as shown in Table 3.4.1 and Figure 3.4.1. The measurement has been carried out at the outlet structure by using a measure; no staff gauge is used so far. The data availability is as shown below:

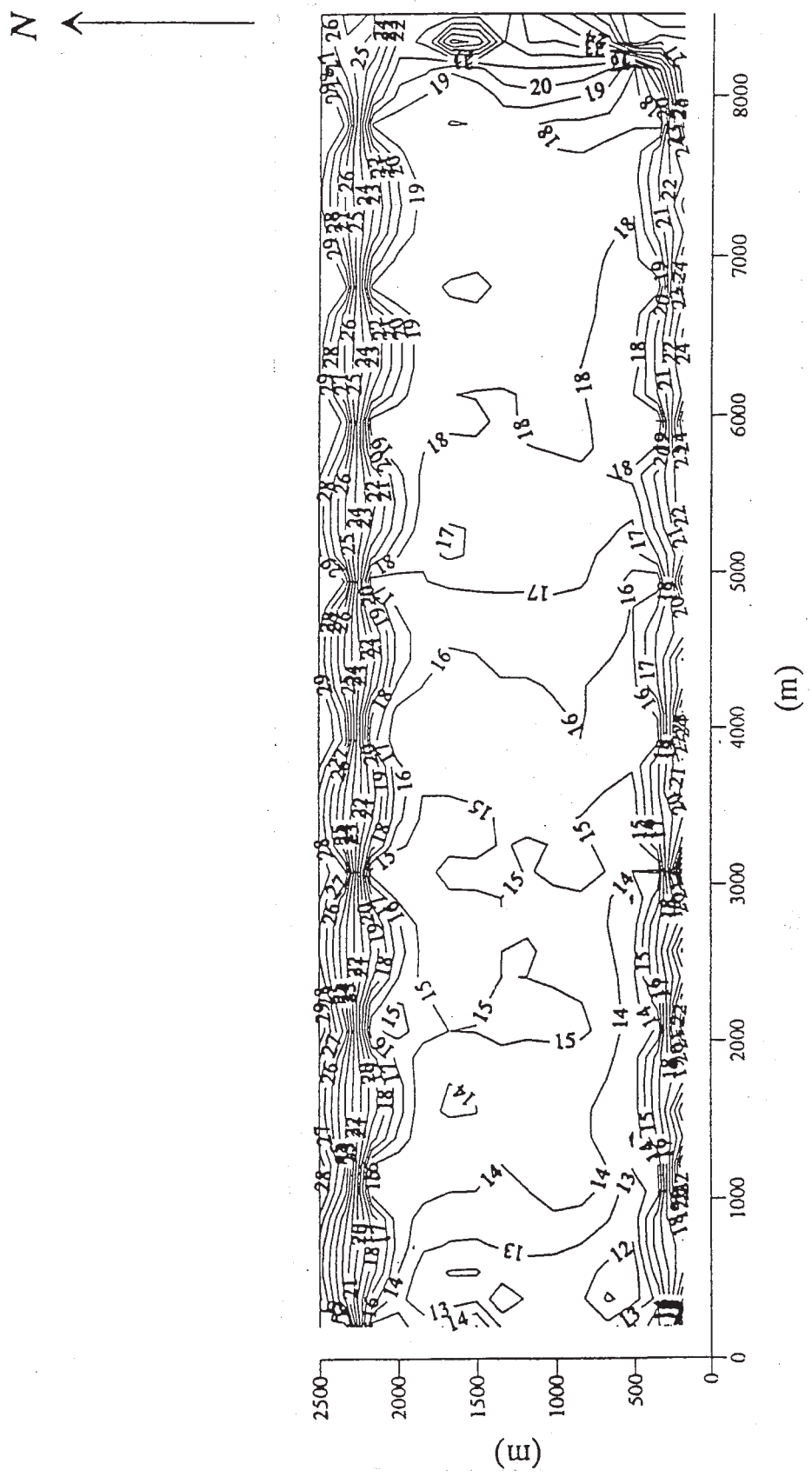
Data Availability of Daily Water Level of West Baray

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1992	-	-	-	-	-	-	-	-	-	@	+	@
1993	#	#	@	@	@	@	@	@	@	@	#	@
1994	@	@	@	@	@	@	@	#	#	-	-	-
1995	#	@	@	@	#	+	@	@	+	-	-	-
1996	-	-	@	@	@	@	@	@	@	@	@	#
1997	-	@	-	-	-	@	@	@	@	@	@	@
1998	-	-	-	-	-	-	-	@	@	@	@	+

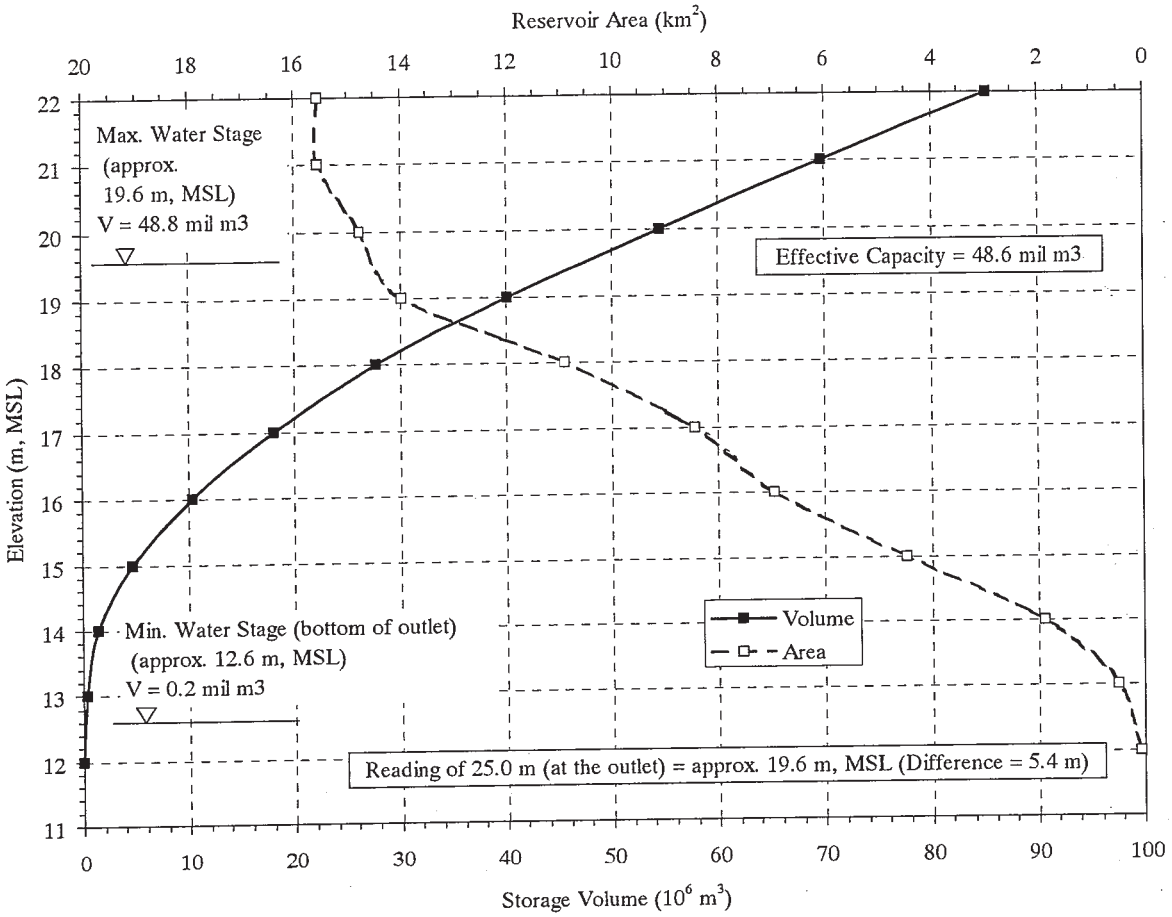
Legend: @: Complete date +: less than 15 days
#: more than 15 days -: data missing

The data missing portion since 1997 has been partly supplemented by the Study Team measurement as shown in the figure.

The maximum and minimum water levels were observed in 1997. The maximum water level in 1997 once reached up to 25.15 m (approx. 19.75 m, MSL) on September 30, since deteriorated American and Takav Gates on the Canal A could not completely stop the flood from the Siem Reap River. Then the reservoir water level urgently lowered to around 24.5 m by opening the gates at the outlet structure in spite of non irrigation season, since the ring dyke was severely damaged. In the end of irrigation season in May 1998, the level was lowered to around 19.50 m



The Study on Water Supply System for Siem Reap Region in Cambodia	Figure 3.3.1 Contour Map of West Baray Reservoir
Japan International Cooperation Agency	



Elevation (H, MSL) (m)	Area (A) (km^2)	Volume (10^6 m^3)	Accumulative Volume (V) (10^6 m^3)
11.2	0.00	0.00	0.00
12	0.06	0.03	0.03
13	0.51	0.29	0.31
14	1.87	1.19	1.50
15	4.46	3.16	4.66
16	6.95	5.70	10.36
17	8.45	7.70	18.06
18	10.90	9.67	27.73
19	13.97	12.43	40.16
20	14.77	14.37	54.53
21	15.56	15.16	69.70
22	15.56	15.56	85.26

The Study on Water Supply System for Siem Reap Region in Cambodia

Japan International Cooperation Agency

Figure 3.3.2
Height, Area and Volume Curve of West Baray Reservoir

Table 3.4.1 Daily Water Stage of West Baray Reservoir (1/4)

Year: 1992 unit: m

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1										23.46	24.66	24.56
2										23.50	24.65	24.54
3										23.55	24.64	24.52
4										23.60	24.62	24.50
5										23.68	24.62	24.49
6										23.70	24.60	24.48
7										23.75	24.60	24.48
8										23.80	24.59	24.47
9										23.85	24.59	24.45
10										23.90	24.59	24.43
11										23.95	24.58	24.42
12										24.00	24.58	24.41
13										24.05	24.58	24.40
14										24.10	24.58	24.40
15										24.15		24.40
16										24.20		24.39
17										24.23		24.37
18										24.25		24.36
19										24.32		24.36
20										24.39		24.35
21										24.45		24.34
22										24.50		24.33
23										24.52		24.31
24										24.52		24.31
25										24.55		24.30
26										24.62		24.30
27										24.65		24.30
28												24.29
29												24.29
30												24.27
31												24.25
Average										24.08	24.61	24.39
Min.										23.46	24.58	24.25
Max.										24.65	**24.66**	24.56

Year: 1993 unit: m

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	24.25	23.72	23.21	22.59	22.29	21.72	22.17	23.00	23.88	24.53	24.67	24.62
2	24.24	23.71	23.18	22.59	22.28	21.72	22.20	23.03	23.88	24.55	24.67	24.59
3	24.23	23.70	23.14	22.59	22.28	21.72	22.20	23.05	23.90	24.55	24.67	24.59
4	24.23	23.68	23.12	22.59	22.27	21.72	22.21	23.07	23.99	24.61	24.67	24.58
5	24.22	23.67	23.08	22.57	22.26	21.71	22.22	23.10	24.02	24.63	24.67	24.56
6	24.22	23.66	23.06	22.56	22.25	21.71	22.23	23.12	24.05	24.64	24.67	24.55
7	24.21	23.64	23.03	22.56	22.24	21.71	22.25	23.14	24.19	24.65	24.67	24.55
8	24.20	23.62	23.01	22.56	22.21	21.71	22.25	23.17	24.35	24.65	24.67	24.53
9	24.18	23.59	23.01	22.56	22.20	21.71	22.25	23.18	24.40	24.67	24.67	24.53
10	24.18	23.56	23.00	22.56	22.19	21.70	22.26	23.18	24.45	24.67	24.67	24.53
11	24.16	23.55	22.99	22.55	22.15	21.70	22.30	23.18	24.46	24.67	24.67	24.50
12	24.14	23.52	22.98	22.54	22.10	21.69	22.35	23.18	24.47	24.67	24.67	24.48
13	24.13	23.49	22.98	22.53	22.05	21.69	22.45	23.19	24.48	24.67	24.67	24.47
14	24.10	23.45	22.97	22.53	22.00	21.69	22.55	23.19	24.48	24.67	24.67	24.45
15	24.08	23.40	22.95	22.51	22.00	21.69	22.65	23.20	24.48	24.67	24.67	24.45
16	24.06	23.39	22.95	22.49	21.99	21.69	22.70	23.21	24.48	24.67	24.67	24.44
17	24.04	23.38	22.95	22.49	21.99	21.69	22.75	23.22	24.49	24.67	24.67	24.44
18	24.04	23.36	22.93	22.49	21.99	21.68	22.80	23.28	24.49	24.67	24.67	24.44
19	24.00	23.35	22.80	22.48	21.98	21.68	22.85	23.29	24.49	24.67	24.67	24.42
20	23.98	23.33	22.80	22.47	21.98	21.67	22.88	23.38	24.50	24.67	24.67	24.41
21	23.96	23.31	22.76	22.46	21.90	21.67	22.90	23.40	24.50	24.67	24.67	24.39
22	23.94	23.30	22.74	22.35	21.88	21.66	22.91	23.45	24.51	24.67	24.67	24.39
23	23.91	23.28	22.70	22.34	21.85	21.65	22.92	23.50	24.51	24.67	24.67	24.38
24	23.90	23.26	22.68	22.34	21.83	21.69	22.92	23.63	24.51	24.67	24.67	24.36
25	23.89	23.25	22.66	22.33	21.80	21.75	22.94	23.70	24.51	24.67	24.67	24.35
26	23.87	23.24	22.65	22.32	21.72	21.90	22.96	23.72	24.51	24.67	24.67	24.34
27	23.84	23.23	22.63	22.31		22.00	22.96	23.75	24.51	24.67	24.67	24.34
28	23.77	23.21	22.61	22.31	21.72	22.05	22.96	23.77	24.51	24.67	24.68	24.33
29			22.60	22.30	21.72	22.07	22.97	23.81	24.51	24.67	24.66	24.32
30			22.59	22.30	21.72	22.10	22.98	23.85	24.51	24.67	24.65	24.31
31					21.72		22.99	23.86				
Average	24.07	23.46	22.89	22.47	22.02	21.75	22.61	23.35	24.37	24.65	24.67	24.45
Min.	23.77	23.21	22.59	22.30	21.72	**21.65**	22.17	23.00	23.88	24.53	24.65	24.31
Max.	24.25	23.72	23.21	22.59	22.29	22.10	22.99	23.86	24.51	24.67	**24.68**	24.62

Source: Hydrology Office in Siem Reap, MOA (measured at 7:00 AM)
Note: Reading of 25.0 m (at the outlet) = approx. 19.6 m, MSL (Difference = 5.4 m)

Table 3.4.1 Daily Water Stage of West Baray Reservoir (2/4)

Year: 1994 unit: m

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	24.30	23.64	22.97	22.48	21.86	21.55	21.47		22.65			
2	24.28	23.62	22.95	22.46	21.85	21.50	21.48		22.75			
3	24.26	23.61	22.93	22.45	21.83	21.47	21.50		22.82			
4	24.25	23.60	22.90	22.37	21.82	21.43	21.55	21.87	22.90			
5	24.23	23.57	22.89	22.36	21.81	21.43	21.60	21.88	23.00			
6	24.22	23.54	22.88	22.35	21.80	21.43	21.65	21.88	23.05			
7	24.21	23.52	22.87	22.34	21.80	21.44	21.65	21.87	23.13			
8	24.20	23.50	22.85	22.31	21.78	21.44	21.67	21.87	23.20			
9	24.18	23.48	22.80	22.30	21.76	21.44	21.67	21.88	23.25			
10	24.17	23.47	22.75	22.29	21.73	21.44	21.67	21.88	23.32			
11	24.16	23.45	22.73	22.27	21.70	21.42	21.68	21.89	23.40			
12	24.16	23.43	22.72	22.25	21.70	21.41	21.70	21.89	23.45			
13	24.15	23.40	22.70	22.23	21.67	21.40	21.71	21.89	23.50			
14	24.12	23.37	22.68	22.21	21.63	21.39	21.72	21.89	23.60			
15	24.09	23.35	22.65	22.20	21.61	21.38	21.73	21.88	23.67			
16	24.08	23.32	22.62	22.19	21.60	21.35	21.75	21.88	23.72			
17	24.03	23.30	22.60	22.17	21.60	21.35	21.77	21.87	23.78			
18	24.00	23.25	22.59	22.14	21.60	21.35	21.78	21.84	23.92			
19	23.98	23.23	22.57	22.12	21.60	21.35	21.79	21.83	24.00			
20	23.94	23.20	22.56	22.10	21.60	21.35	21.80	21.81	24.05			
21	23.92	23.18	22.55	22.09	21.60	21.35	21.80	21.80	24.00			
22	23.88	23.17	22.55	22.06	21.59	21.35	21.81	21.80	24.05			
23	23.84	23.15	22.54	22.04	21.57	21.35	21.82	21.81	24.15			
24	23.81	23.10	22.53	22.03	21.57	21.35	21.83	21.85	24.20			
25	23.78	23.05	22.52	21.98	21.57	21.35	21.84	22.00	24.25			
26	23.75	23.03	22.51	21.95	21.57	21.35	21.84	22.09	24.30			
27	23.72	23.00	22.50	21.94	21.56	21.35	21.84	22.07	24.35			
28	23.70	22.99	22.50	21.92	21.55	21.40	21.85	22.30	24.40			
29	23.69		22.50	21.89	21.55	21.43	21.85	22.40	24.45			
30	23.67		22.50		21.56	21.45	21.85	22.50				
31	23.65		22.49		21.57		21.85	22.60				
Average	24.01	23.34	22.67	22.19	21.66	21.40	21.73	21.97	23.63			
Min.	23.65	22.99	22.49	21.89	21.55	**21.35**	21.47	21.80	22.65			
Max.	24.30	23.64	22.97	22.48	21.86	21.55	21.85	22.60	**24.45**			

Year: 1995 unit: m

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1		22.99	22.15	21.09	20.32		20.14	20.66	21.85			
2		22.98	22.00	21.08	20.31		20.16	20.67	21.90			
3	23.75	22.96	22.05	21.04	20.20		20.18	20.70	21.95			
4		22.95	22.00	21.01	20.20		20.20	20.75	22.02			
5		22.90	21.95	21.00	20.20		20.22	20.90	22.10			
6	23.65	22.88	21.93	20.99	20.20		20.22	21.00	22.15			
7		22.86	21.90	20.97	20.20		20.24	21.03	22.20			
8		22.85	21.85	20.95	20.18		20.25	21.06	22.27			
9		22.84	21.83	20.93	20.16		20.25	21.18	22.32			
10	23.55	22.83	21.80	20.91	20.14		20.26	21.24	22.39			
11		22.80	21.78	20.90	20.14		20.27	21.30	22.45			
12		22.78	21.76	20.88	20.14		20.28	21.32	22.50			
13		22.76	21.74	20.86	20.13		20.28	21.33	22.58			
14		22.75	21.72	20.84	20.01		20.29	21.35				
15		22.73	21.70	20.80	20.10		20.32	21.37				
16	23.45	22.71	21.68	20.75			20.33	21.38				
17		22.70	21.64	20.70			20.35	21.39				
18		22.65	21.62	20.67			20.40	21.40				
19		22.58	21.60	20.64			20.45	21.40				
20		22.50	21.57	20.60			20.50	21.40				
21	23.30	22.45	21.54	20.55			20.52	21.41				
22		22.42	21.47	20.50			20.52	21.41				
23		22.36	21.40	20.48	20.00		20.53	21.45				
24		22.33	21.36	20.45			20.54	21.46				
25	23.20	22.28	21.28	20.44			20.55	21.50				
26		22.24	21.20	20.42			20.58	21.55				
27	23.15	22.20	21.20	20.40		20.10	20.60	21.60				
28		22.17	21.17	20.37		20.12	20.62	21.65				
29			21.15	20.35		20.12	20.63	21.69				
30	23.05		21.12	20.33		20.13	20.63	21.75				
31	23.00						20.63	21.79				
Average	23.34	22.66	21.64	20.73	20.16	20.12	20.39	21.29	22.21			
Min.	23.00	22.17	21.12	20.33	**20.00**	20.10	20.14	20.66	21.85			
Max.	23.75	22.99	22.15	21.09	20.32	20.13	20.63	21.79	22.58			

Source: Hydrology Office in Siem Reap, MOA (measured at 7:00 AM)
Note: Reading of 25.0 m (at the outlet) = approx. 19.6 m, MSL (Difference = 5.4 m)

Table 3.4.1 Daily Water Stage of West Baray Reservoir (3/4)

Year: 1996 unit: m

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1			23.10	21.91	21.60	21.56	21.62	21.71	21.86	23.10	24.63	
2			23.05	21.90	21.59	21.55	21.61	21.72	21.86	23.20	24.66	
3			23.00	21.89	21.59	21.53	21.60	21.72	21.87	23.25	24.69	
4			22.98	21.88	21.58	21.52	21.60	21.71	21.87	23.34	24.73	
5			22.96	21.86	21.58	21.51	21.60	21.73	21.89	23.40	24.79	
6			22.95	21.85	21.55	21.53	21.60	21.73	21.94	23.47	24.80	
7			22.85	21.84	21.55	21.53	21.60	21.75	22.00	23.55	24.82	
8			22.78	21.82	21.55	21.54	21.60	21.80	22.07	23.60	24.83	
9			22.77	21.81	21.55	21.55	21.59	21.82	22.14	23.66	24.83	
10			22.76	21.80	21.55	21.57	21.59	21.86	22.24	23.75	24.83	
11			22.75	21.79	21.55	21.57	21.58	21.86	22.29	23.80	24.83	
12			22.70	21.78	21.55	21.55	21.59	21.87	22.31	23.85	24.83	
13			22.65	21.76	21.56	21.55	21.60	21.86	22.35	23.90	24.84	
14			22.62	21.75	21.56	21.60	21.60	21.86	22.38	23.97	24.84	
15			22.60	21.74	21.56	21.60	21.60	21.85	22.41	23.99	24.85	
16			22.55	21.73	21.55	21.64	21.59	21.85	22.44	24.01	24.87	
17			22.50	21.72	21.55	21.67	21.59	21.84	22.47	24.05	24.88	
18			22.45	21.71	21.56	21.65	21.58	21.84	22.51	24.09	24.90	
19			22.41	21.70	21.56	21.66	21.58	21.84	22.55	24.14	24.91	
20			22.38	21.70	21.56	21.66	21.58	21.83	22.57	24.17	24.92	
21			22.34	21.70	21.60	21.65	21.58	21.82	22.60	24.20	24.92	
22			22.29	21.70	21.60	21.64	21.59	21.81	22.62	24.27	24.92	
23			22.25	21.67	21.60	21.63	21.59	21.80	22.64	24.32	24.92	
24			22.20	21.63	21.60	21.64	21.59	21.81	22.68	24.35	24.92	
25			22.15	21.61	21.60	21.65	21.59	21.82	22.70	24.38	24.92	
26			22.10	21.59	21.60	21.63	21.59	21.85	22.73	24.41	24.92	
27			22.05	21.57	21.60	21.61	21.60	21.85	22.76	24.50	24.92	
28			22.00	21.55	21.60	21.61	21.61	21.85	22.81	24.51	24.92	
29			21.95	21.55	21.60	21.63	21.62	21.86	22.91	24.53	24.92	
30			21.93	21.53	21.60	21.62	21.69	21.86	23.00	24.55	24.92	
31			21.91		21.58		21.70	21.86		24.58		
Average			22.52	21.73	21.58	21.60	21.60	21.81	22.38	23.96	24.85	
Min.			21.91	21.53	21.55	**21.51**	21.58	21.71	21.86	23.10	24.63	
Max.			23.10	21.91	21.60	21.67	21.70	21.87	23.00	24.58	**24.92**	

Year: 1997 unit: m

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	24.57					21.91	22.00	22.91	24.29	25.15	24.80	24.55
2	24.56					21.91	22.00	22.96	24.33	25.12	24.80	24.55
3	24.55					21.91	21.99	23.06	24.36	25.09	24.80	24.53
4	24.54					21.94	21.98	23.16	24.38	25.09	24.79	24.52
5	24.52					21.98	21.98	23.23	24.41	25.08	24.78	24.51
6	24.52					21.98	21.97	23.30	24.43	25.04	24.77	24.50
7	24.52					21.98	21.97	23.35	24.45	25.00	24.76	24.48
8	24.51					21.97	21.96	23.40	24.46	24.98	24.75	24.48
9	24.51					21.97	21.95	23.45	24.45	24.95	24.74	24.44
10	24.51					21.97	22.00	23.50	24.44	24.92	24.73	24.42
11	24.51					21.97	22.04	23.50	24.43	24.90	24.72	24.40
12	24.51					21.97	22.07	23.60	24.42	24.88	24.72	24.38
13	24.50					21.97	22.10	23.63	24.43	24.86	24.71	24.36
14	24.50					21.97	22.14	23.66	24.44	24.84	24.70	24.34
15	24.49					21.97	22.18	23.70	24.46	24.84	24.69	24.30
16	24.48					21.98	22.20	23.73	24.53	24.86	24.69	24.28
17	24.48					21.97	22.22	23.75	24.58	24.85	24.68	24.26
18	24.48					21.97	22.24	23.77	24.62	24.85	24.67	24.24
19	24.47					21.97	22.27	23.80	24.66	24.83	24.67	24.22
20	24.47					21.97	22.29	23.82	24.75	24.81	24.66	24.20
21	24.47					21.97	22.31	23.84	24.82	24.81	24.65	24.18
22	24.47					21.98	22.36	23.85	24.85	24.81	24.64	24.16
23	24.46					21.98	22.40	23.90	24.88	24.81	24.62	24.14
24	24.45					21.99	22.44	23.96	24.88	24.81	24.61	24.11
25	24.44					21.99	22.47	23.99	24.87	24.81	24.60	24.09
26	24.40					21.99	22.51	24.05	24.92	24.81	24.59	24.07
27	24.39					21.99	22.55	24.08	25.06	24.81	24.58	24.05
28	24.38					22.00	22.58	24.10	25.10	24.81	24.56	24.02
29	24.37					22.00	22.64	24.15	25.11	24.80	24.56	24.00
30						22.00	22.70	24.20	25.15	24.80	24.56	23.98
							22.84	24.24		24.80		23.96
Average						21.97	22.24	23.67	24.63	24.90	24.69	24.28
Min.						**21.91**	21.95	22.91	24.29	24.80	24.56	23.96
Max.						22.00	22.84	24.24	**25.15**	25.15	24.80	24.55

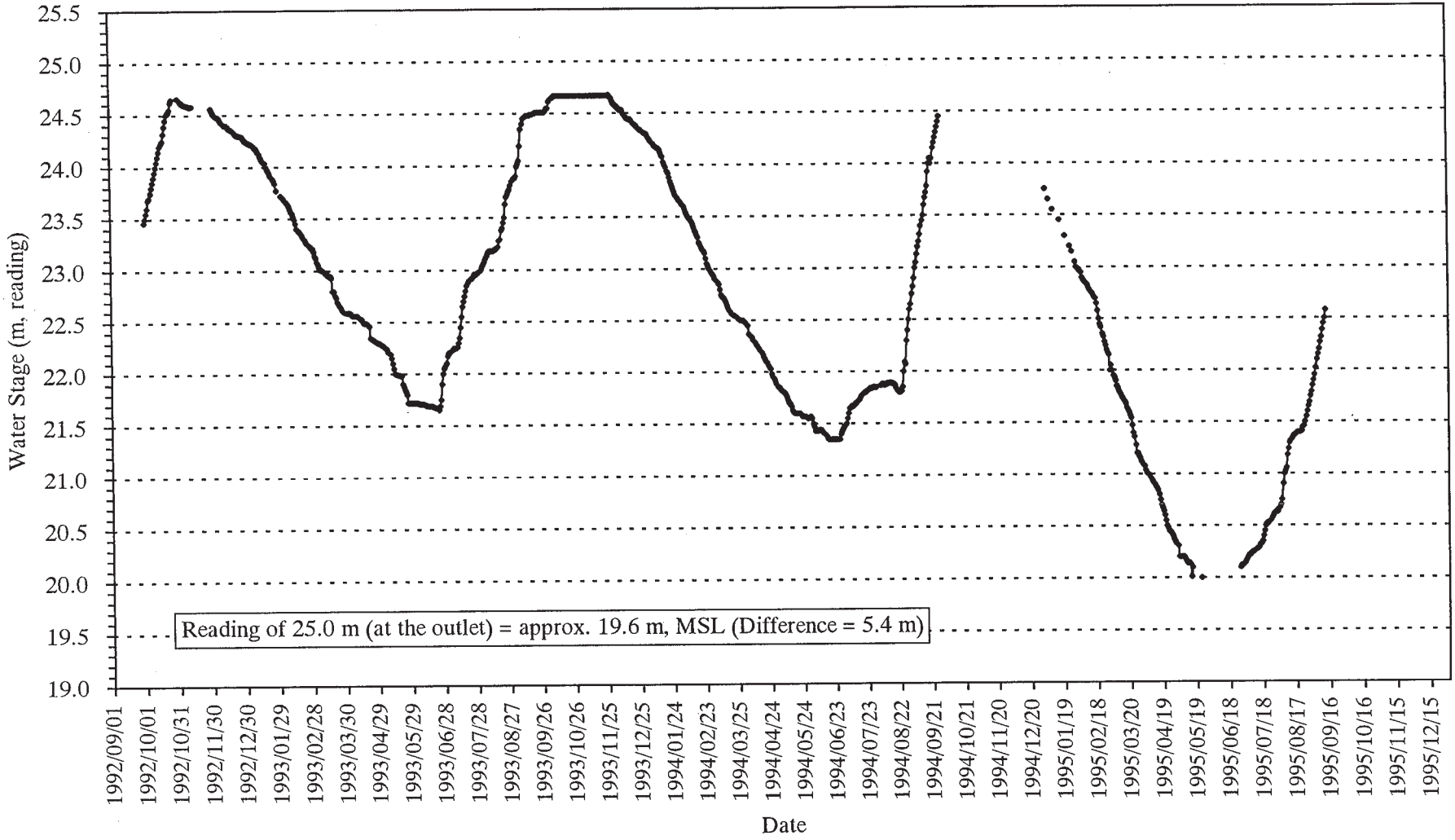
Source: Hydrology Office in Siem Reap, MOA (measured at 7:00 AM)
Note: Reading of 25.0 m (at the outlet) = approx. 19.6 m, MSL (Difference = 5.4 m)

Table 3.4.1 Daily Water Stage of West Baray Reservoir (4/4)

Year: 1998 unit: m

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	23.94							19.50	20.69	21.89	23.41	23.91
2	23.93							19.54	20.70	21.95	23.42	23.92
3	23.92							19.56	20.71	22.00	23.44	23.94
4	23.91							19.60	20.72	22.10	23.45	23.95
5	23.90							19.65	20.73	22.15	23.50	23.97
6	23.88							19.71	20.75	22.20	23.55	23.98
7	23.86							19.77	20.76	22.25	23.60	24.00
8	23.86							19.82	20.77	22.30	23.65	
9	23.88							19.86	20.78	22.37	23.65	
10	23.80							19.92	20.79	22.43	23.65	
11	23.78							20.00	20.80	22.45	23.65	
12	23.76							20.10	20.85	22.50	23.65	
13	23.73							20.17	20.87	22.55	23.70	
14	23.71							20.19	20.88	22.65	23.74	
15	23.69							20.20	20.90	22.70	23.77	
16	23.67							20.25	20.95	22.77	23.80	
17	23.65							20.30	20.98	22.85	23.83	
18	23.64							20.32	21.00	22.90	23.87	
19	23.62							20.34	21.05	22.95	23.90	
20	23.60							20.37	21.10	23.00	23.90	
21	23.58							20.39	21.15	23.07	23.90	
22	23.56							20.40	21.20	23.10	23.90	
23	23.54							20.42	21.25	23.12	23.90	
24	23.51							20.45	21.31	23.13	23.90	
25	23.48							20.52	21.38	23.15	23.90	
26	23.45							20.57	21.43	23.20	23.90	
27	23.42							20.61	21.52	23.30	23.90	
28	23.39							20.63	21.60	23.34	23.90	
29	23.36							20.65	21.66	23.35	23.90	
30	23.33							20.67	21.76	23.37	23.90	
31	23.30							20.68		23.40		
Average	23.67							20.17	21.03	22.73	23.74	23.95
Min.	23.30							**19.50**	20.69	21.89	23.41	23.91
Max.	23.94							20.68	21.76	23.40	23.90	**24.00**

Source: Hydrology Office in Siem Reap, MOA (measured at 7:00 AM)
Note: Reading of 25.0 m (at the outlet) = approx. 19.6 m, MSL (Difference = 5.4 m)

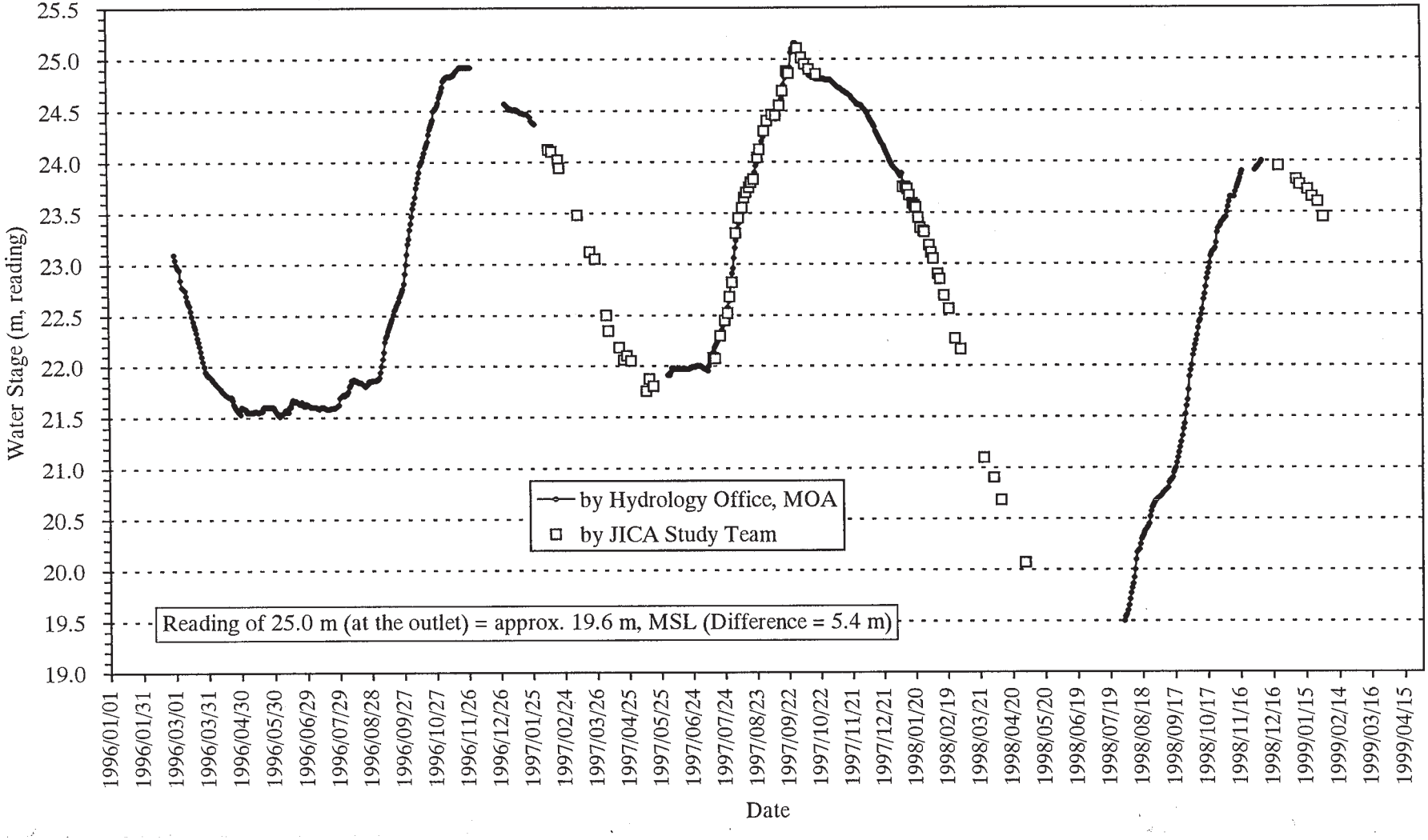


Source: Hydrology Office in Siem Reap, MOA

The Study on Water Supply System for Siem Reap Region in Cambodia

Japan International Cooperation Agency

Figure 3.4.1
Daily Water Stage of West Baray Reservoir (1/2) <1992 – 1995>



Source: Hydrology Office in Siem Reap, MOA

The Study on Water Supply System for Siem Reap Region in Cambodia

Japan International Cooperation Agency

Figure 3.4.1
Daily Water Stage of West Baray Reservoir (2/2) <1996 – 1998>

(approx. 14.10 m, MSL) because of big demand for irrigation (refer to Table 2.5.1). The reservoir was nearly empty at that time (refer to Figure 3.3.1). This large level lowering does not seem only for the protection of the ring dyke.

3.5 Historical Change of Standard Water Level

The historical change of the standard (maximum) water level is as follows according to the Hungarian Study, 1993 and the interview survey at the Hydrology Office:

Period	Standard Water Level
from 1930's up to 1940's	26.5 m (approx. 21.1 m, MSL)
between 1979 and 1985	25.5 m (approx. 20.1 m, MSL)
from 1986	24.5 m (approx. 19.1 m, MSL)

It is known that the West Mebon was under water before 1940. The maximum level in 1998 was limited to 24.0 m, the current standard level decided by MOA is 25.0 m, though. The reason of the limitation is the severe deterioration of the ring dyke caused by the big flood in 1997.

3.6 Preliminary Water Balance Review

The preliminary water balance review of the reservoir is conducted based on the rising and falling curves of the reservoir level hydrograph since 1992. The storage by rainfall and loss by evaporation are estimated by using the same methodology applied in section 2.4. The estimate of the storage in the rainy season and the water use in the dry season is shown in Table 3.6.1 and Figure 3.6.1. Present standard water level of 25.0 m (19.6 m, MSL) is applied for the review.

The estimated average storage pattern during the rainy season is summarized as follows:

Average Storage Pattern of West Baray during Rainy Season

Breakdown	Capacity (10^6 m^3)	Ratio (%)
Uncharged capacity	5.5	11
Inflow from Siem Reap River	23.8	49
Storage by rainfall - Loss by evaporation	9.8	20
Previous reminder of irrigation use	9.9	20
Total	49.0	100

Note; Data period: 1992-1998, no data is available in 1992 and 1995.

The total capacity becomes bigger than the effective capacity at 25.0 m (48.6 million m^3), since the over storage to 25.15 m in 1997 is taken into account.

Table 3.6.1 Estimated Water Balance of West Baray Reservoir (1/2)

Storage of Reservoir

Period	Min. Water Stage (start of storage)				Max. Water Stage (end of storage)				Difference of Capacity (C) (B)-(A)	Previous Reminder of Irrigation Use (D) (A)-Vol.min	Storage by Rainfall (during min. stage and max. stage)					Inflow from Siem Reap River			Uncharged Capacity
	Date	Water Stage		Capacity (A)	Date	Water Stage		Capacity (B)			Lake Evaporation		Rainfall		Difference (G) (F)-(E)	(C)-(G)			Vol.max-(B)
		Reading	MSL			Reading	MSL					(E)		(F)					
		(m)	(m)	(10^6 m^3)		(m)	(m)	(10^6 m^3)			(mm)	(10^6 m^3)	(mm)	(10^6 m^3)	(10^6 m^3)	(10^6 m^3)	(day)	(m^3/s)	(10^6 m^3)
1992	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1993	1993/06/23	21.65	16.25	12.29	1993/10/09	24.67	19.27	44.04	31.75	12.09	307.9	3.08	879.0	13.68	10.60	21.15	108	2.27	4.74
1994	1994/06/27	21.35	15.95	10.08	1994/09/29	24.45	19.05	40.88	30.80	9.88	266.6	2.67	742.3	11.55	8.88	21.92	94	2.70	7.90
1995	1995/06/27	20.10	14.70	3.71	-	-	-	-	-		-		-		-	-	-	-	-
1996	1996/07/26	21.59	16.19	11.82	1996/11/20	24.92	19.52	47.63	35.81	11.62	297.9	2.98	781.0	12.15	9.17	26.64	117	2.64	1.15
1997	1997/07/09	21.95	16.55	14.60	1997/09/30	25.15	19.75	50.94	36.34	14.40	235.5	2.36	817.7	12.72	10.36	25.98	83	3.62	0.00
1998	1998/08/01	19.50	14.10	1.82	1998/12/07	24.00	18.60	35.19	33.37	1.62	347.0	3.47	875.8	13.63	10.16	23.21	128	2.10	13.59
Average		21.02	15.62	9.05		24.64	19.24	43.74	33.61	9.92	291.0	2.91	819.2	12.75	9.83	23.78	106	2.66	5.48

Note: Reading of 25.0 m (at the outlet) = approx. 19.6 m, MSL (Difference = 5.4 m)

Vol.max <Capacity at max. water stage (19.6 m, MSL)> = 48.8 (10^6 m^3)

Vol.min <Capacity at min. water stage (12.6 m, MSL)> = 0.2 (10^6 m^3)

Effective capacity = 48.6 (10^6 m^3)

Total reservoir area= 15.6 (km^2)

Approx. max. total area of water surface = 10 (km^2)

Er= 0.7 *Ep

where; Er: Lake Evaporation

Ep: Pan Evaporation

Table 3.6.1 Estimated Water Balance of West Baray Reservoir (2/2)

Water Use of Reservoir

Period	Max. Water Stage (start of irrigation)				Min. Water Stage (end of irrigation)				Difference of Capacity (C) (A)-(B)	Reminder of Irrigatio Use (D) (B)-Vol.min	Loss by Evaporation (during max. stage and min. stage)					Supplied Capacity			Uncharged Capacity (H) Vol.max-(A)	Potential Capacity (D)+(H)
	Date	Water Stage		Capacity	Date	Water Stage		Capacity			Lake Evaporation		Rainfall		Difference					
		Reading	MSL	(A)		Reading	MSL	(B)				(E)		(F)	(G)					
															(E)-(F)	(C)-(G)				
		(m)	(m)	(10^6 m^3)		(m)	(m)	(10^6 m^3)		(10^6 m^3)	(mm)	(10^6 m^3)	(mm)	(10^6 m^3)	(10^6 m^3)	(10^6 m^3)	(day)	(m^3/s)	(10^6 m^3)	(10^6 m^3)
1992 - 1993	1992/12/01	24.56	19.16	42.46	1993/05/29	21.72	16.32	12.82	29.64	12.62	562.2	5.62	98.2	1.53	4.09	25.55	179	1.65	6.32	18.94
1993 - 1994	1993/11/28	24.68	19.28	44.18	1994/06/16	21.35	15.95	10.08	34.10	9.88	624.9	6.25	161.4	2.51	3.74	30.36	200	1.76	4.60	14.48
1994 - 1995	(1994/12/01)	(24.45)	19.05	40.88	1995/05/23	20.00	14.60	3.40	37.48	3.20	542.1	5.42	192.8	3.00	2.42	35.06	173	2.35	7.90	11.10
1995 - 1996	-	-	-	-	1996/04/30	21.53	16.13	11.36	-	-	-		-		-	-	-	-	-	
1996 - 1997	(1996/11/30)	24.92	19.52	47.63	(1997/05/12)	(21.75)	16.35	13.06	34.57	12.86	507.7	5.08	231.8	3.61	1.47	33.10	163	2.35	1.15	14.01
1997 - 1998	(1997/12/06)	(24.50)	19.10	41.60	(1998/05/31)	(19.50)	14.10	1.82	39.78	1.62	550.8	5.51	112.4	1.75	3.76	36.02	176	2.37	7.18	8.80
1998 - 1999	1998/12/07	24.00	18.60	34.95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Average		24.52	19.12	41.95		20.98	15.58	8.76	35.11	8.04	557.5	5.58	159.3	2.48	3.10	32.02	178	2.09	5.43	13.47

Note: Reading of 25.0 m (at the outlet) = approx. 19.6 m, MSL (Difference = 5.4 m)

Vol.max <Capacity at max. water stage (19.6 m, MSL)> = 48.8 (10^6 m^3)

Vol.min <Capacity at min. water stage (12.6 m, MSL)> = 0.2 (10^6 m^3)

Effective capacity = 48.6 (10^6 m^3)

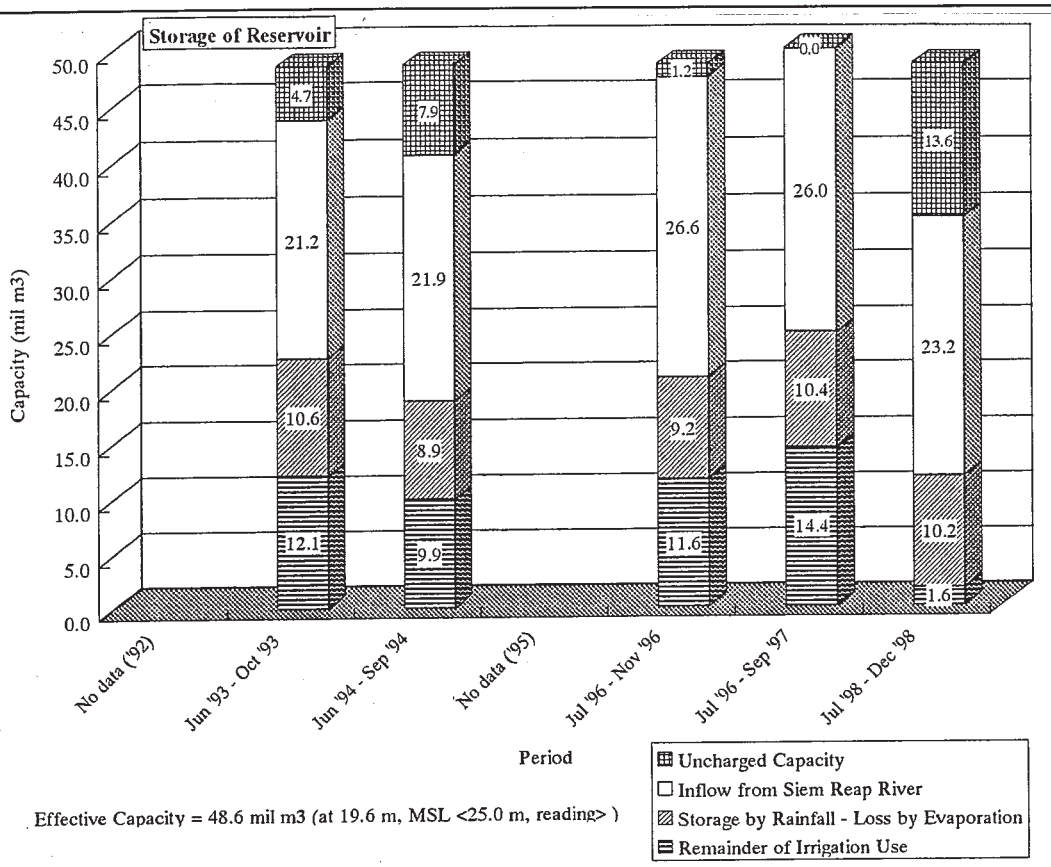
Total reservoir area= 15.56 (km^2)

Approx. max. total area of water surface = 10 (km^2)

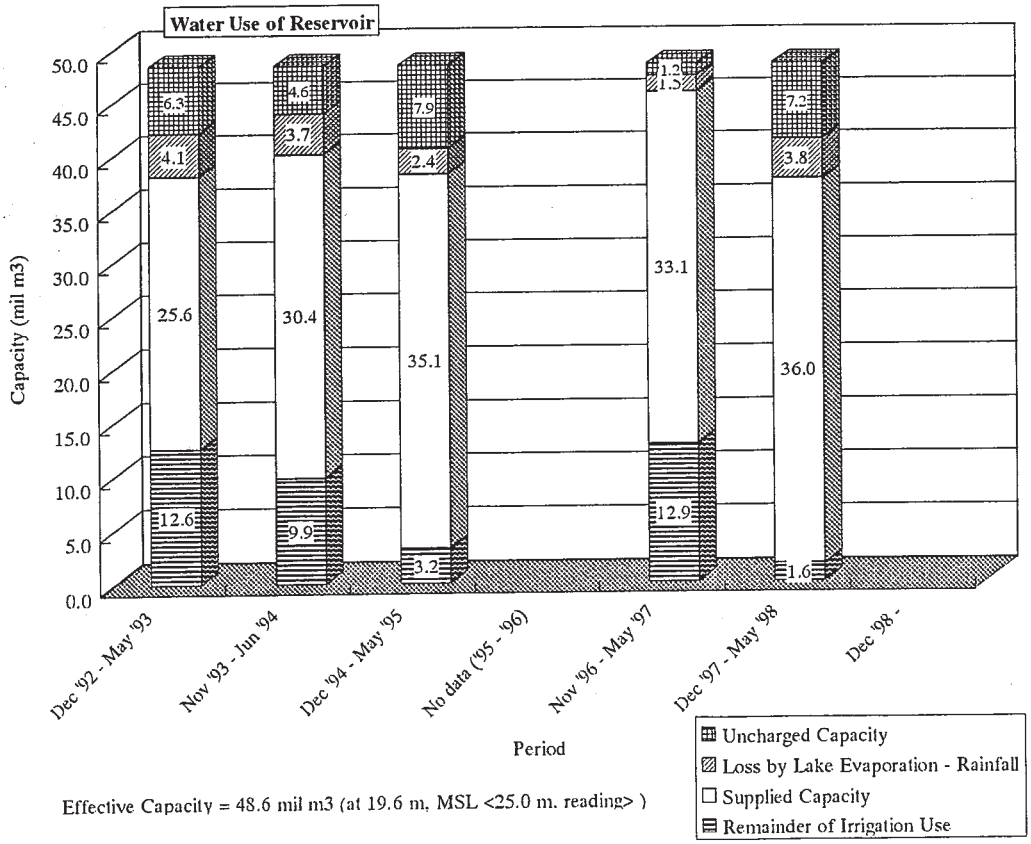
Er= 0.7 *Ep

where; Er: Lake Evaporation

Ep: Pan Evaporation



Effective Capacity = 48.6 mil m3 (at 19.6 m, MSL <25.0 m, reading>)



Effective Capacity = 48.6 mil m3 (at 19.6 m, MSL <25.0 m, reading>)

The Study on Water Supply System for Siem Reap Region in Cambodia

Japan International Cooperation Agency

Figure 3.6.1
Estimated Water Balance of West Baray Reservoir

The inflow from the Siem Reap River accounts for close to a half of the total storage during the rainy season.

The estimated average water use pattern in the reservoir during the dry season is summarized as follows:

Average Water Use Pattern of West Baray during Dry Season

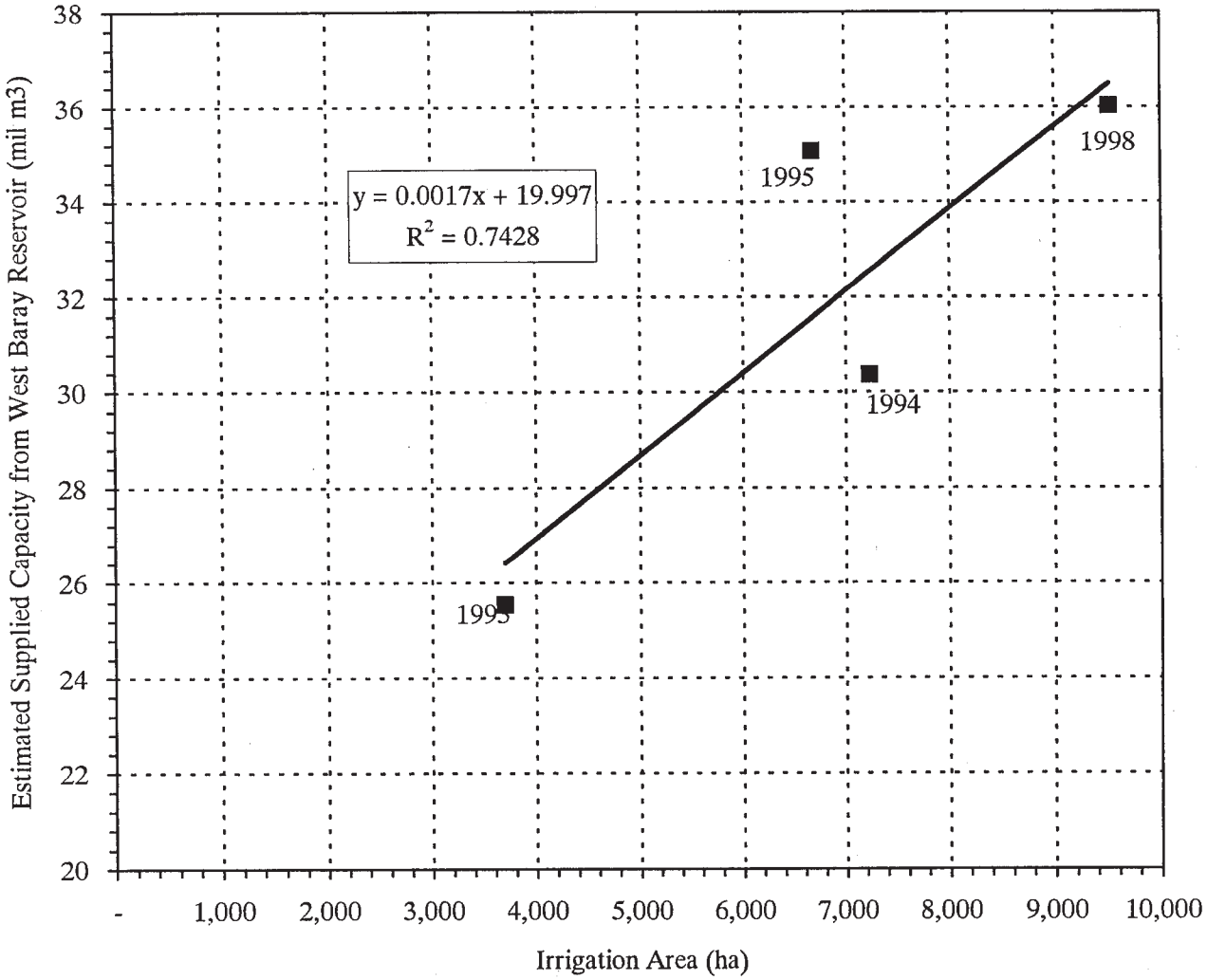
Breakdown	Capacity (10^6 m^3)	Ratio (%)
Uncharged capacity	5.4	11
Loss by evaporation - Storage by rainfall	3.1	6
Supplied capacity for irrigation	32.0	66
Reminder of irrigation use	8.1	17
Total (= effective capacity)	48.6	100

Note; Data period: 1992-1998, no data is available in 1995-1996 and 1998-.

The supplied capacity for irrigation is 32.0 million m^3 on average, which account for 66% of the total effective capacity. Average irrigation period is around 180 days and the flow is around 2 m^3/s on average during this period. The maximum and minimum supply capacity was 36.0 million m^3 in 1998 and 25.6 million m^3 in 1993, respectively. Around 6% of effective capacity is lost by evaporation during the dry (irrigation) season.

The relationship between the supplied capacity and the irrigation area is shown in Figure 3.6.2. There is a certain measure of correlation between both figures, as supplied water is currently used at a low efficiency owing to the deterioration of the irrigation canal network.

The remainder of irrigation use reaches 8.1 million m^3 on average, which equates to 22,100 m^3/day for 12 months. The uncharged capacity also reaches 5.4 million m^3 on average, which equals 14,800 m^3/day for 12 months. The storage from the Siem Reap River to the reservoir and the water use for irrigation seems carried out at low efficiencies. This is because of the deteriorated condition from the French Weir to the irrigation canals and the lack of effective reservoir operation. More water resources can be produced from the present reservoir by introducing an effective integrated reservoir operation.



The Study on Water Supply System for Siem Reap Region in Cambodia	**Figure 3.6.2 Irrigation Area and Supplied Capacity from West Baray Reservoir**
Japan International Cooperation Agency	

4. Hydrological Condition of Lake Tonle Sap

4.1 General

The Lake Tonle Sap is the largest permanent freshwater lake in Southeast Asia. It is connected to the Mekong by the Tonle Sap River at the conjunction in Phnom Penh. The water level of the lake drops less than EL. 1 m at the end of dry season and rises up to EL. 8 to 10 m at the end of the rainy season. During the rainy season, the water of the Mekong overflows backwards into the lake through the Tonle Sap River. For this reason, the level of the lake rises by 7 to 8 m, roughly quadrupling the water surface from around 2,500 km^2 to more than 13,000 km^2, thereby displacing the lakeshore by 20 to 50 km. During the dry season, the flow in the Tonle Sap River is reversed and the lake drains into the Mekong. This phenomenon is extremely rare in the world. At low water level, the lake is about 120 km long and up to 35 km wide. Peak flooding by the lake usually occurs in September or October.

In the Study Area, there is a relative deep channel emerging from the lake towards the Siem Reap Town that is used for navigation and harboring. A large number of floating villages surrounds the shoreline.

4.2 Daily Water Level

In the Study Area, the daily water level of the lake (at 7:00 AM) has been measured continuously by Fisherman's Office in Siem Reap, MOA since May 1996 as shown in Table 4.2.1 and Figure 4.2.1. The measurement has been carried out along the road extending from Phnom Krom by shifting staff gauge according to lakeshore shifting.

Table 4.2.1 Daily Water Stage of Lake Tonle Sap at Siem Reap (1/2)

Year: 1996 unit: m, MSL

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1						1.08	1.93	3.02	5.52	8.33	9.76	8.80
2						1.18	1.97	3.02	5.62	8.47	9.74	8.75
3						1.21	2.00	3.12	5.70	8.62	9.70	8.71
4						1.21	2.02	3.24	5.73	8.77	9.66	8.67
5						1.17	2.04	3.37	5.78	9.02	9.64	8.63
6						1.14	2.07	3.43	5.81	9.26	9.60	8.58
7						1.16	2.11	3.53	5.84	9.50	9.58	8.53
8						1.16	2.14	3.60	5.89	9.61	9.56	8.49
9						1.16	2.18	3.70	5.89	9.69	9.54	8.43
10						1.24	2.18	3.80	5.95	9.77	9.54	8.39
11						1.28	2.20	3.90	5.99	9.82	9.52	8.33
12						1.32	2.27	4.00	6.07	9.87	9.50	8.27
13						1.32	2.27	4.09	6.11	9.87	9.49	8.19
14						1.34	2.27	4.17	6.19	9.87	9.48	8.14
15						1.38	2.31	4.29	6.23	9.87	9.45	8.09
16						1.41	2.33	4.39	6.25	9.89	9.42	8.04
17						1.44	2.33	4.49	6.29	9.87	9.38	7.90
18						1.41	2.33	4.57	6.35	9.87	9.33	7.83
19						1.51	2.33	4.67	6.41	9.85	9.31	7.79
20					0.80	1.56	2.37	4.74	6.47	9.83	9.27	7.71
21					0.81	1.58	2.40	4.82	6.53	9.82	9.22	7.63
22					0.83	1.63	2.43	4.90	6.66	9.81	9.18	7.57
23					0.83	1.63	2.45	4.98	6.81	9.79	9.14	7.53
24					0.85	1.69	2.48	5.06	7.05	9.77	9.10	7.48
25					0.89	1.81	2.55	5.16	7.32	9.77	9.06	7.40
26					0.89	1.85	2.58	5.24	7.52	9.84	9.00	7.36
27					0.93	1.85	2.63	5.27	7.72	9.80	8.97	7.28
28					0.97	1.87	2.73	5.34	7.90	9.80	8.92	7.22
29					1.03	1.87	2.87	5.42	8.05	9.80	8.87	7.16
30					1.08	1.90	2.84	5.46	8.20	9.78	8.87	7.10
31					1.08		2.94	5.46		9.76		7.05
Average					0.92	1.45	2.34	4.33	6.46	9.59	9.36	7.97
Min.					**0.80**	1.08	1.93	3.02	5.52	8.33	8.87	7.05
Max.					1.08	1.90	2.94	5.46	8.20	**9.89**	9.76	8.80

Year: 1997 unit: m, MSL

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	7.00	5.59	4.26	2.74	1.12	0.78	0.94	3.77	7.86	9.08	8.82	6.98
2	6.97	5.53	4.21	2.62	1.11	0.78	0.94	3.93	7.90	9.09	8.77	6.95
3	6.91	5.50	4.16	2.48	1.08	0.76	0.94	4.12	7.96	9.10	8.71	6.88
4	6.85	5.46	4.10	2.35	1.08	0.76	0.96	4.29	8.00	9.13	8.66	6.80
5	6.80	5.42	4.02	2.30	1.08	0.76	1.05	4.39	8.06	9.20	8.57	6.72
6	6.75	5.38	3.97	2.08	1.07	0.76	1.13	4.51	8.10	9.25	8.49	6.65
7	6.69	5.32	3.91	1.95	1.07	0.79	1.23	4.76	8.18	9.27	8.41	6.60
8	6.65	5.27	3.86	1.83	1.07	0.83	1.33	5.03	8.20	9.27	8.34	6.54
9	6.60	5.23	3.81	1.71	1.06	0.85	1.41	5.31	8.25	9.27	8.28	6.47
10	6.55	5.17	3.76	1.62	1.04	0.85	1.53	5.58	8.29	9.27	8.22	6.43
11	6.52	5.13	3.70	1.53	1.02	0.88	1.63	5.87	8.31	9.27	8.15	6.40
12	6.46	5.07	3.65	1.47	1.00	0.89	1.72	6.15	8.34	9.27	8.08	6.37
13	6.40	5.03	3.61	1.44	0.99	0.90	1.85	6.36	8.37	9.27	8.00	6.33
14	6.35	5.01	3.58	1.42	0.99	0.90	1.96	6.56	8.39	9.27	7.95	6.30
15	6.33	4.96	3.54	1.39	0.99	0.88	2.01	6.71	8.41	9.27	7.87	6.27
16	6.31	4.93	3.50	1.37	0.98	0.86	2.09	6.83	8.44	9.27	7.82	6.24
17	6.27	4.90	3.46	1.37	0.97	0.86	2.19	6.93	8.47	9.27	7.78	6.20
18	6.22	4.84	3.43	1.37	0.97	0.86	2.29	6.99	8.54	9.27	7.73	6.17
19	6.18	4.78	3.38	1.37	0.96	0.86	2.37	7.04	8.57	9.27	7.66	6.12
20	6.13	4.73	3.34	1.36	0.94	0.86	2.47	7.05	8.61	9.27	7.58	6.07
21	6.07	4.68	3.30	1.36	0.90	0.87	2.54	7.09	8.64	9.25	7.52	6.01
22	6.01	4.62	3.27	1.34	0.88	0.85	2.64	7.15	8.67	9.23	7.46	5.97
23	5.95	4.56	3.24	1.30	0.85	0.84	2.74	7.23	8.69	9.20	7.39	5.92
24	5.90	4.51	3.21	1.26	0.85	0.87	2.89	7.35	8.71	9.17	7.31	5.87
25	5.86	4.46	3.17	1.21	0.85	0.89	2.99	7.43	8.71	9.13	7.26	5.83
26	5.86	4.42	3.13	1.19	0.84	0.89	3.09	7.53	8.77	9.09	7.21	5.79
27	5.80	4.37	3.09	1.17	0.84	0.89	3.19	7.58	8.79	9.06	7.16	5.76
28	5.76	4.30	3.02	1.14	0.82	0.91	3.34	7.64	8.89	9.02	7.12	5.71
29	5.71		2.98	1.14	0.82	0.91	3.49	7.70	9.04	8.99	7.08	5.64
30	5.67		2.93	1.14	0.80	0.92	3.59	7.77	9.06	8.94	7.03	5.56
31	5.63		2.84		0.80		3.69	7.82		8.89		5.48
Average	6.30	4.97	3.53	1.60	0.96	0.85	2.14	6.27	8.44	9.18	7.88	6.23
Min.	**5.63**	4.30	2.84	1.14	0.80	0.76	0.94	3.77	7.86	8.89	7.03	5.48
Max.	7.00	5.59	4.26	2.74	1.12	0.92	3.69	7.82	9.06	**9.27**	8.82	6.98

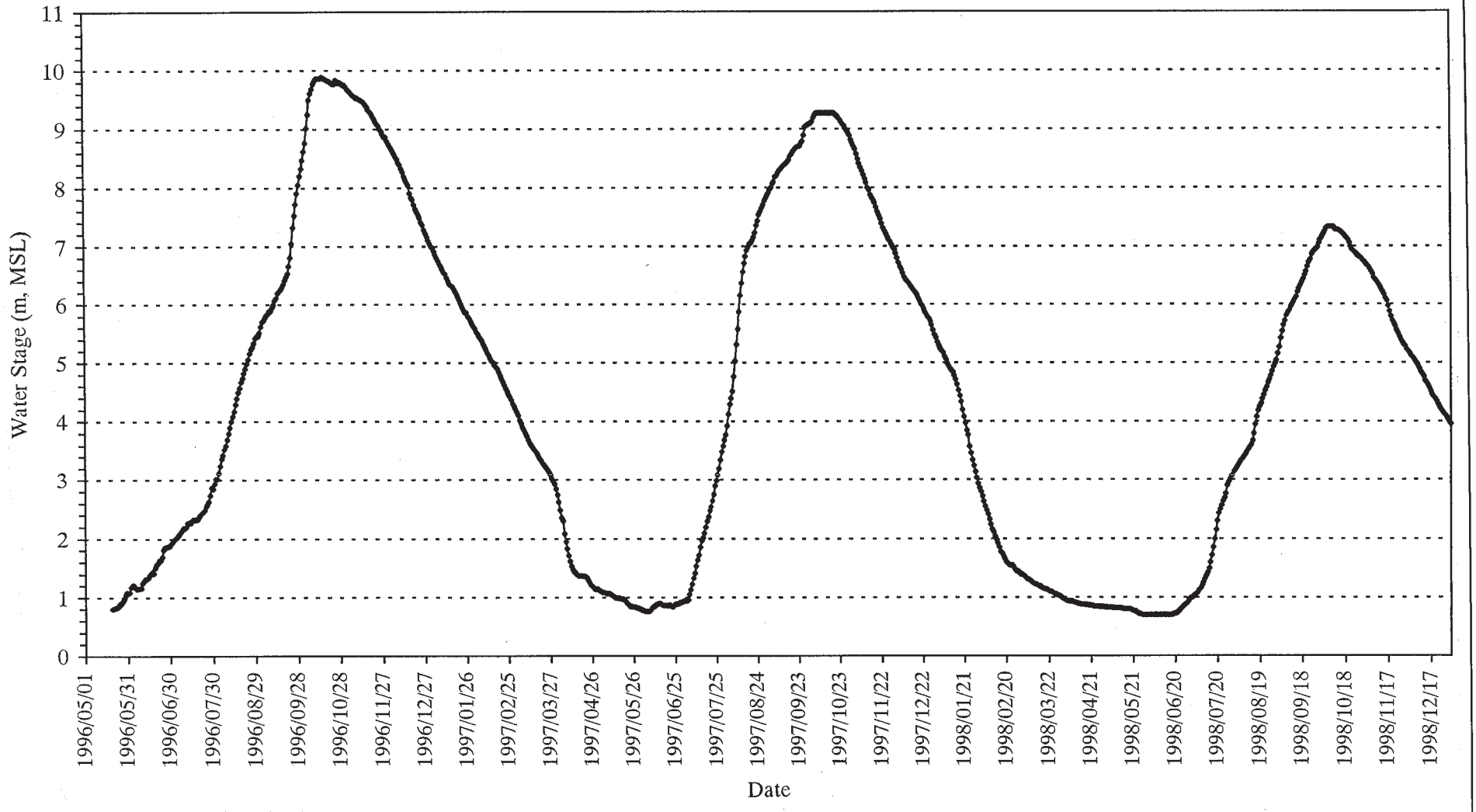
Source: Fisherman's Office in Siem Reap, MOA (measured at 7:00 AM)

Table 4.2.1 Daily Water Stage of Lake Tonle Sap at Siem Reap (2/2)

Year: 1998 unit: m, MSL

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	5.43	2.86	1.43	0.98	0.84	0.70	0.99	3.15	5.16	7.11	6.71	5.20
2	5.36	2.79	1.40	0.97	0.83	0.70	1.00	3.18	5.27	7.15	6.68	5.17
3	5.30	2.72	1.40	0.96	0.83	0.70	1.03	3.22	5.42	7.20	6.66	5.13
4	5.25	2.63	1.38	0.94	0.83	0.70	1.05	3.27	5.54	7.25	6.62	5.10
5	5.21	2.55	1.36	0.94	0.83	0.70	1.06	3.30	5.64	7.31	6.57	5.07
6	5.18	2.48	1.33	0.93	0.83	0.70	1.09	3.34	5.72	7.33	6.52	5.03
7	5.11	2.41	1.31	0.94	0.82	0.70	1.13	3.37	5.81	7.33	6.46	4.99
8	5.06	2.33	1.31	0.93	0.82	0.70	1.16	3.41	5.86	7.33	6.42	4.96
9	5.00	2.24	1.29	0.91	0.82	0.70	1.21	3.44	5.90	7.33	6.39	4.91
10	4.95	2.16	1.26	0.91	0.82	0.70	1.26	3.49	5.96	7.33	6.35	4.85
11	4.91	2.11		0.90	0.82	0.70	1.32	3.53	5.99	7.28	6.30	4.81
12	4.87	2.04	1.23	0.90	0.82	0.70	1.38	3.58	6.03	7.28	6.26	4.76
13	4.84	1.98	1.23	0.89	0.81	0.70	1.43	3.61	6.08	7.28	6.22	4.70
14	4.78	1.92	1.21	0.88	0.80	0.70	1.50	3.68	6.13	7.26	6.17	4.66
15	4.71	1.85	1.19	0.88	0.80	0.70	1.60	3.80	6.21	7.24	6.10	4.62
16	4.63	1.78	1.19	0.88	0.80	0.70	1.72	3.95	6.27	7.22	6.06	4.57
17	4.53	1.74	1.17	0.88	0.80	0.70	1.85	4.08	6.32	7.20	5.97	4.51
18	4.43	1.69	1.16	0.87	0.80	0.70	2.00	4.19	6.38	7.17	5.88	4.46
19	4.33	1.65	1.14	0.87	0.80	0.72	2.15	4.26	6.44	7.14	5.80	4.42
20	4.20	1.60	1.14	0.86	0.79	0.73	2.30	4.31	6.51	7.11	5.72	4.39
21	4.08	1.57	1.13	0.86	0.77	0.73	2.43	4.38	6.57	7.06	5.67	4.35
22	3.98	1.55	1.11	0.86	0.77	0.76	2.50	4.45	6.65	6.99	5.63	4.30
23	3.85	1.55	1.10	0.85	0.76	0.78	2.56	4.53	6.73	6.94	5.56	4.25
24	3.77	1.55	1.10	0.85	0.74	0.81	2.64	4.59	6.78	6.91	5.51	4.21
25	3.58	1.52	1.08	0.85	0.72	0.83	2.69	4.66	6.86	6.89	5.45	4.18
26	3.46	1.48	1.06	0.85	0.72	0.86	2.76	4.71	6.90	6.87	5.39	4.14
27	3.34	1.45	1.06	0.85	0.70	0.88	2.90	4.78	6.93	6.84	5.35	4.11
28	3.24	1.45	1.04	0.84	0.70	0.90	2.96	4.86	6.95	6.82	5.31	4.08
29	3.14		1.03	0.84	0.70	0.93	3.01	4.93	6.98	6.80	5.29	4.04
30	3.04		1.02	0.84	0.70	0.97	3.07	4.99	7.05	6.77	5.23	3.99
31	2.94		1.00		0.70			5.04		6.74		3.96
Average	4.40	1.99	1.20	0.89	0.78	0.75	1.86	4.00	6.23	7.11	6.01	4.58
Min.	2.94	1.45	1.00	0.84	**0.70**	0.70	0.99	3.15	5.16	6.74	5.23	3.96
Max.	5.43	2.86	1.43	0.98	0.84	0.97	3.07	5.04	7.05	**7.33**	6.71	5.20

Source:
Fisherman's Office in Siem Reap, MOA (measured at 7:00 AM)



Source: Fisherman's Office in Siem Reap, MOA

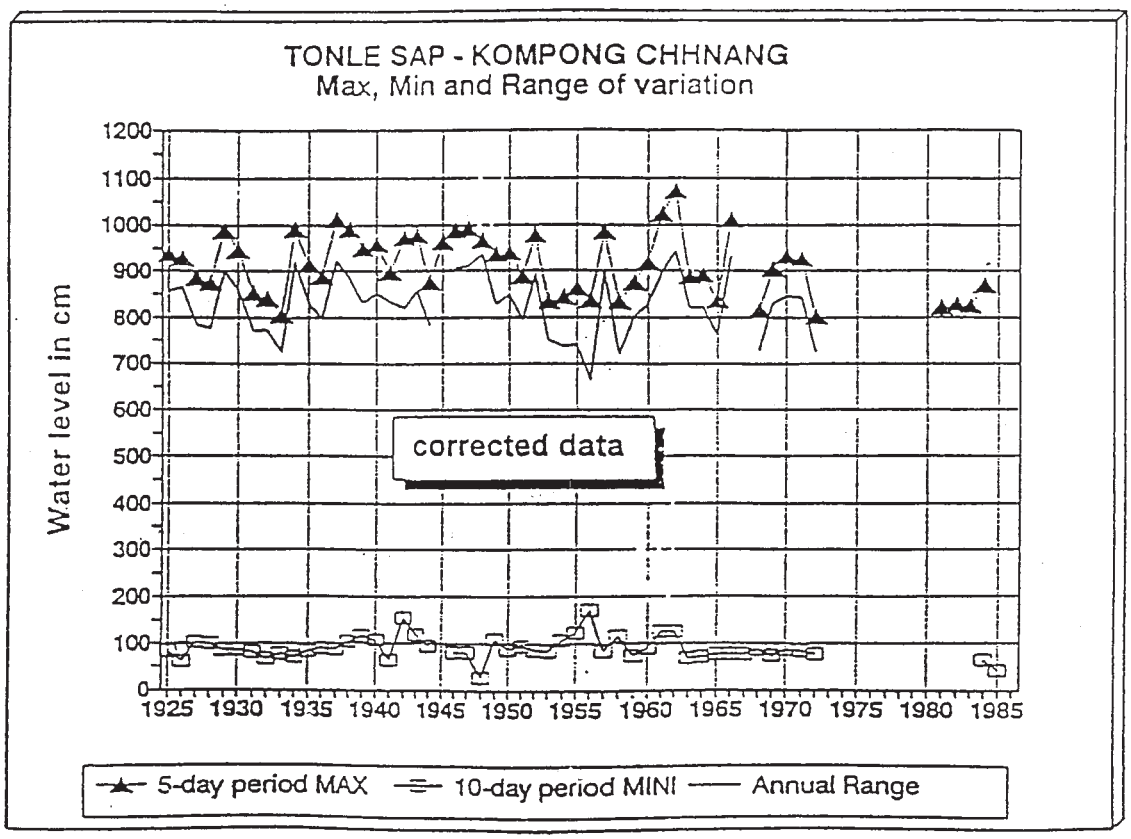
The Study on Water Supply System for Siem Reap Region in Cambodia	**Figure 4.2.1** Daily Water Stage of Lake Tonle Sap <at Siem Reap (1996 – 1998)>
Japan International Cooperation Agency	

4.3 Probable Water Levels

Long-term maximum and minimum levels are shown in Figure 4.3.1. According to "Review of the Hydrology Sector in Cambodia" (MOA, 1997), the probable maximum and minimum levels are analyzed as follows:

Probable Water Level of Lake Tonle Sap

Return Period	Maximum Water Level (m, MSL)	Minimum Water Level (m, MSL)
2-year	9.23	1.05
5-year	9.69	0.84
10-year	9.94	0.75
20-year	10.15	0.68



Source: Mekong Secretariat (October 1993)

"Development Plan for Tonle Sap and Chakdomuk, Phase I, Final Report"

The Study on Water Supply System for Siem Reap Region in Cambodia	**Figure 4.3.1 Max and Min Water Stages of Lake Tonle Sap**
Japan International Cooperation Agency	

5. Evaluation of Surface Water Sources

5.1 Siem Reap River

(1) Estimate of 10-year Flow Hydrograph

The 10-year flow hydrograph at the French Weir from 1989 to 1998 was used to decide the 10-year drought discharge and the reference dry year as a basis of the study on the availability of raw water.

The only flow hydrograph available is as of 1998 prepared in section 2. Therefore, as for the flow regime from 1989 to 1997, there is no choice but to generate roughly by expanding and contracting the flow pattern in 1998 based on the monthly rainfall pattern in Siem Reap. The monthly rainfall is shown in Table 5.1.1 and Figure 5.1.1. The runoff volume of each month is estimated based on the following relationship with monthly rainfall as shown in the double mass curve in Figure 2.4.8:

$$V=0.048R+7.169$$

where; V: runoff volume (million m^3)
R: monthly rainfall (mm)

After estimating flow pattern, the annual runoff volume of estimated pattern is adjusted to the ratio of annual rainfall. The 5-day flow hydrograph at the weir is prepared for 10 years as shown in Table 5.1.2 and Figure 5.1.2. The 5-day flow is prepared based on the estimated daily flow in order to carry out water balance review; the hydrograph can be utilized as a basis of various kinds of water balance calculations.

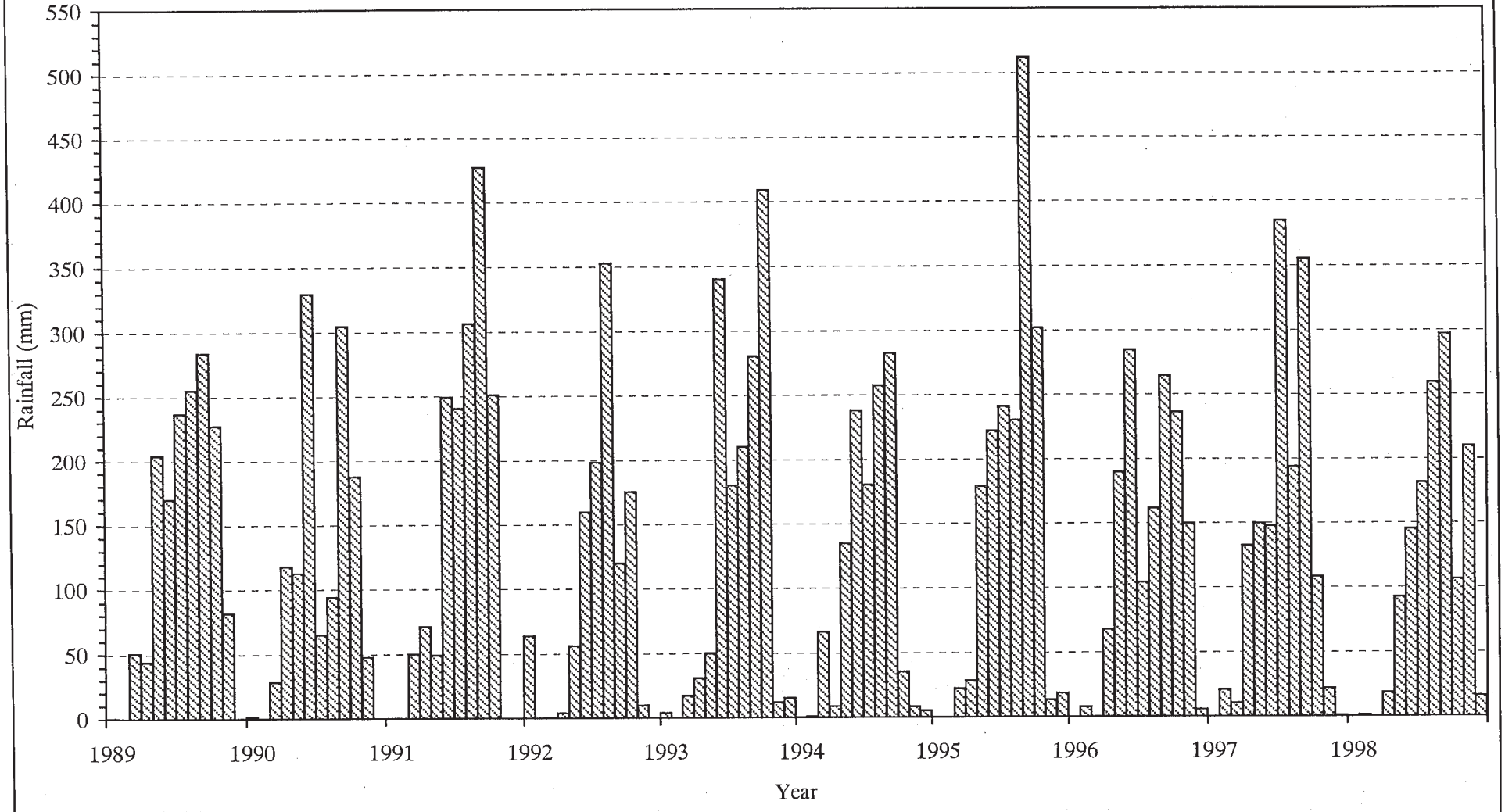
(2) Available Intake Site

One of the causes of abandonment of Old American water supply system, which took raw water from the Siem Reap River, is said to be the deterioration of raw water quality of the river. The deterioration may be caused by the stagnation resulting from the construction of the Crocodile Weir in 1986. The backwater effect of the weir reaches to the military compound located upstream of the UNTAC Bridge; the distance is approximately 3.5 km from the town center. Accordingly, it is preferable that intake site be located upstream of the backwater.

On the other hand, the river runs through the heritage area in the upper reaches of the Angkor Bridge that is located around 6.5 km from the town center. Therefore, in view of the preservation of those heritages, it is recommended that the intake be located in the lower reaches of the Angkor Bridge.

Table 5.1.1 Monthly Rainfall in Siem Reap (at Airport, 1979 - 1998)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1979	4.0	15.2	28.2	60.0	(800.5)	102.8	76.2	124.6	91.5	40.4	16.0	153.0	(1512.4)
1980	-	13.0	33.0	55.0	133.0	187.0	173.0	192.0	249.0	264.0	73.0	19.0	1391.0
1981	50.0	24.0	176.0	81.1	237.0	169.2	180.3	130.6	185.0	129.7	179.0	-	1541.9
1982	-	-	42.8	48.8	74.9	208.7	192.0	216.9	224.1	175.2	42.0	-	1225.4
1983	-	-	17.0	-	228.8	210.0	87.0	251.0	324.0	367.0	101.0	-	1585.8
1984	-	-	5.0	36.0	170.0	144.0	124.0	182.0	115.0	302.0	4.0	-	1082.0
1985	-	-	129.0	75.0	294.0	226.0	130.0	109.0	112.0	113.0	40.0	-	1228.0
1986	-	-	-	93.0	240.0	146.0	133.3	460.5	279.1	376.2	13.8	31.0	1772.9
1987	-	-	17.5	60.0	138.2	169.2	129.8	138.0	313.9	176.0	104.5	-	1247.1
1988	-	0.0	0.9	37.8	135.7	268.3	100.0	243.6	286.9	190.5	28.5	0.0	1292.2
1989	0.5	-	50.7	44.2	204.3	169.8	236.8	255.0	283.9	227.0	81.6	-	1553.8
1990	1.5	0.0	28.3	117.9	112.7	329.6	64.8	94.0	304.8	187.2	47.9	0.0	1288.7
1991	-	0.1	50.0	71.0	49.3	249.3	240.1	306.1	426.9	250.6	0.0	0.0	1643.4
1992	63.6	0.0	-	4.0	56.0	159.3	197.8	352.8	120.1	174.7	9.7	0.0	1138.0
1993	3.7	-	17.2	30.5	50.0	340.2	179.2	210.0	280.4	408.9	12.2	15.2	1547.5
1994	0.0	0.6	66.3	8.7	134.5	237.9	179.8	257.5	282.7	35.3	8.3	5.0	1216.6
1995	-	-	22.0	28.5	179.1	221.6	240.7	230.0	512.1	302.0	13.3	18.1	1767.4
1996	-	7.4	0.1	67.7	189.1	284.7	104.1	161.1	264.3	235.8	149.5	5.4	1469.2
1997	-	20.7	10.5	132.4	149.4	147.4	384.7	193.2	355.2	108.1	21.8	0.8	1524.2
1998	-	1.3	-	18.2	92.3	145.2	180.8	259.3	296.8	106.4	209.7	16.1	1326.1
Average	6.2	4.1	34.7	53.5	(151.0)	205.8	166.7	218.4	265.4	208.5	57.8	13.2	1417.7
Min.	-	-	-	-	49.3	102.8	64.8	94.0	91.5	35.3	0.0	-	1082.0
Max.	63.6	24.0	176.0	132.4	(294.0)	340.2	384.7	460.5	512.1	408.9	209.7	153.0	1772.9



Source: Hydrology Office in Siem Reap, MOA

The Study on Water Supply System for Siem Reap Region in Cambodia

Japan International Cooperation Agency

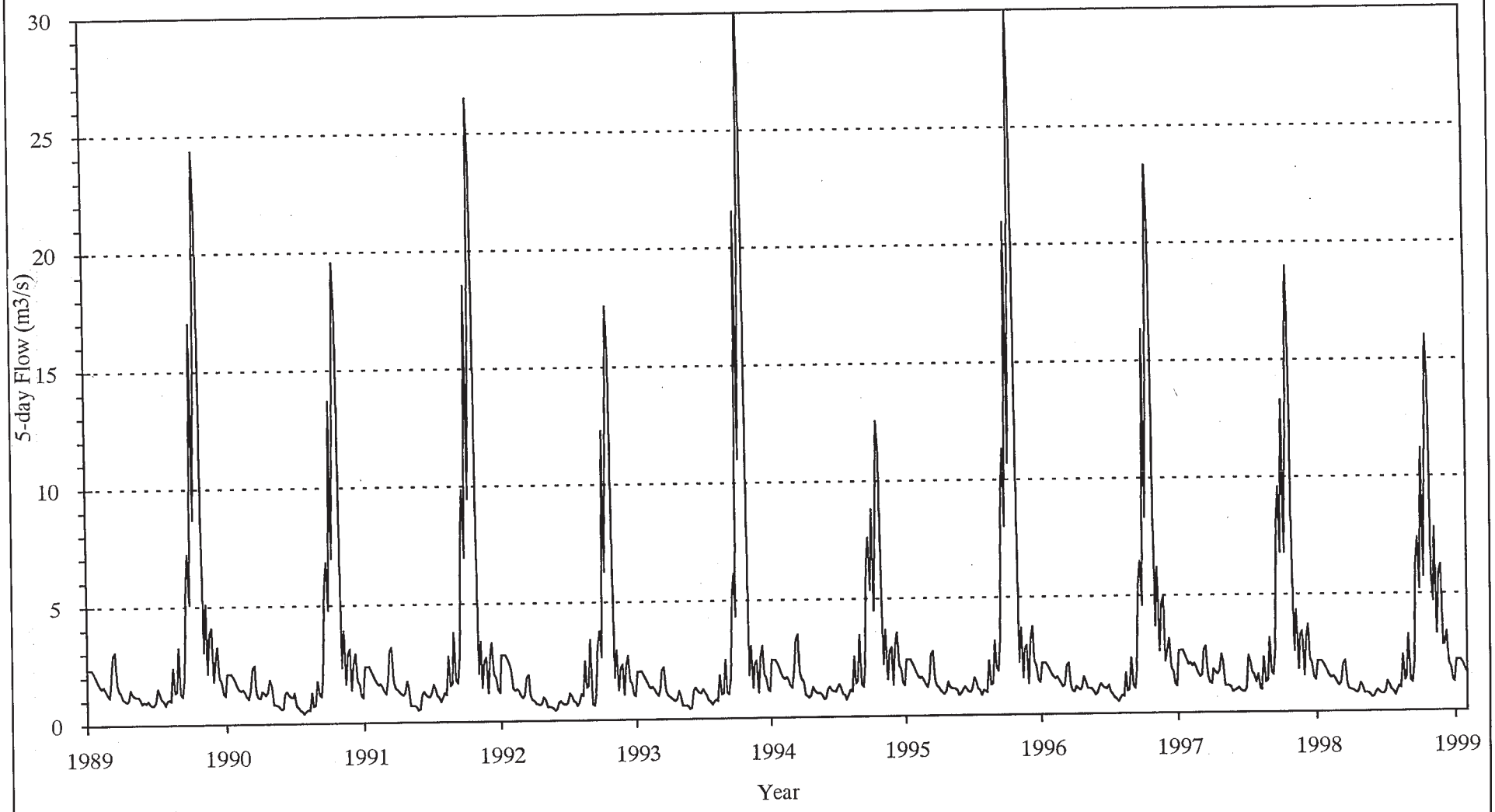
Figure 5.1.1
Monthly Rainfall in Siem Reap
<at Airport (1989 – 1998)>

Table 5.1.2 Estimated 10-year Flow Hydrograph at French Weir (5-day Flow)

(Prasat Keo + Inflow to West Baray Reservoir)

unit: m^3/s

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Volume (10^6 m^3)	97.0	80.6	102.7	71.0	96.6	76.0	110.4	91.9	95.4	83.0
Date										
Jan 01~05	2.34	2.12	2.38	2.79	2.04	2.45	2.39	2.18	2.65	2.16
Jan 06~10	2.34	2.12	2.38	2.79	2.04	2.45	2.39	2.18	2.65	2.16
Jan 11~15	2.35	2.13	2.40	2.80	2.05	2.46	2.40	2.19	2.66	2.17
Jan 16~20	2.20	1.99	2.25	2.62	1.92	2.31	2.25	2.05	2.50	2.03
Jan 21~25	2.02	1.83	2.06	2.41	1.76	2.12	2.07	1.89	2.29	1.87
Jan 26~31	1.81	1.64	1.85	2.17	1.58	1.90	1.86	1.69	2.06	1.68
Feb 01~05	1.63	1.47	1.67	1.37	1.39	1.72	1.67	1.60	2.11	1.52
Feb 06~10	1.55	1.39	1.58	1.30	1.32	1.63	1.59	1.51	2.00	1.44
Feb 11~15	1.62	1.46	1.66	1.36	1.38	1.71	1.66	1.59	2.10	1.51
Feb 16~20	1.47	1.33	1.52	1.24	1.26	1.56	1.51	1.45	1.92	1.38
Feb 21~25	1.30	1.16	1.33	1.09	1.10	1.36	1.33	1.27	1.68	1.21
Feb 26~28	1.17	1.06	1.20	0.98	1.00	1.25	1.20	1.16	1.53	1.10
Mar 01~05	1.77	1.42	1.81	1.11	1.26	2.01	1.56	1.24	1.62	1.23
Mar 06~10	2.94	2.35	3.00	1.84	2.08	3.33	2.58	2.06	2.67	2.03
Mar 11~15	3.10	2.48	3.17	1.94	2.20	3.51	2.73	2.17	2.82	2.15
Mar 16~20	1.71	1.37	1.75	1.08	1.22	1.95	1.51	1.20	1.56	1.19
Mar 21~25	1.41	1.13	1.44	0.89	1.01	1.60	1.24	0.99	1.28	0.98
Mar 26~31	1.35	1.07	1.37	0.84	0.96	1.52	1.18	0.94	1.22	0.93
Apr 01~05	1.11	1.38	1.30	0.73	0.88	0.95	1.05	1.17	1.84	0.90
Apr 06~10	1.03	1.29	1.21	0.69	0.82	0.89	0.97	1.09	1.71	0.84
Apr 11~15	0.98	1.21	1.14	0.65	0.77	0.83	0.92	1.02	1.62	0.79
Apr 16~20	1.07	1.33	1.25	0.71	0.85	0.92	1.01	1.12	1.77	0.87
Apr 21~25	1.49	1.86	1.74	0.99	1.18	1.28	1.41	1.57	2.47	1.21
Apr 26~30	1.29	1.60	1.50	0.86	1.02	1.11	1.22	1.35	2.13	1.05
May 01~05	1.20	0.80	0.70	0.58	0.57	1.01	1.14	1.07	1.15	0.79
May 06~10	1.19	0.80	0.69	0.59	0.58	1.01	1.14	1.07	1.15	0.79
May 11~15	1.19	0.79	0.69	0.58	0.57	1.01	1.13	1.07	1.14	0.78
May 16~20	1.09	0.73	0.63	0.53	0.52	0.92	1.04	0.98	1.05	0.72
May 21~25	0.89	0.59	0.51	0.43	0.43	0.75	0.85	0.80	0.86	0.59
May 26~31	0.98	0.65	0.56	0.48	0.47	0.82	0.93	0.88	0.94	0.64
Jun 01~05	0.92	1.24	1.17	0.75	1.20	1.17	1.09	1.17	0.97	0.83
Jun 06~10	1.01	1.36	1.29	0.82	1.32	1.28	1.20	1.28	1.06	0.90
Jun 11~15	0.89	1.20	1.14	0.73	1.16	1.13	1.07	1.14	0.94	0.80
Jun 16~20	0.83	1.13	1.08	0.68	1.10	1.07	1.00	1.07	0.88	0.75
Jun 21~25	0.82	1.11	1.05	0.67	1.08	1.05	0.98	1.05	0.87	0.74
Jun 26~30	0.95	1.29	1.22	0.77	1.25	1.21	1.14	1.21	1.01	0.86
Jul 01~05	1.53	0.76	1.58	1.15	1.11	1.37	1.58	0.94	2.41	1.28
Jul 06~10	1.35	0.67	1.39	1.02	0.98	1.21	1.40	0.83	2.12	1.13
Jul 11~15	1.08	0.54	1.12	0.81	0.78	0.96	1.12	0.67	1.70	0.90
Jul 16~20	1.01	0.50	1.04	0.76	0.73	0.90	1.05	0.62	1.59	0.84
Jul 21~25	0.82	0.41	0.84	0.61	0.59	0.73	0.85	0.50	1.28	0.68
Jul 26~30	1.02	0.51	1.06	0.77	0.74	0.92	1.06	0.63	1.61	0.86
Aug 01~05	1.06	0.57	1.22	1.11	0.80	1.12	1.02	0.76	1.02	1.06
Aug 06~10	0.99	0.54	1.15	1.03	0.75	1.05	0.95	0.71	0.95	0.99
Aug 11~15	2.40	1.30	2.77	2.50	1.82	2.53	2.31	1.72	2.32	2.39
Aug 16~20	1.33	0.72	1.53	1.38	1.01	1.40	1.28	0.95	1.28	1.32
Aug 21~25	1.42	0.76	1.63	1.47	1.07	1.50	1.36	1.02	1.36	1.41
Aug 26~30	3.26	1.77	3.77	3.40	2.47	3.45	3.14	2.34	3.15	3.26
Sep 01~05	1.29	1.22	1.77	0.67	1.10	1.36	2.03	1.16	1.72	1.32
Sep 06~10	1.19	1.12	1.62	0.62	1.01	1.24	1.86	1.06	1.58	1.21
Sep 11~15	2.03	1.92	2.77	1.06	1.72	2.13	3.18	1.82	2.69	2.08
Sep 16~20	6.00	5.66	8.18	3.13	5.08	6.29	9.40	5.36	7.95	6.12
Sep 21~25	7.22	6.81	9.84	3.77	6.11	7.57	11.31	6.45	9.57	7.36
Sep 26~30	5.11	4.81	6.96	2.67	4.32	5.36	8.00	4.57	6.77	5.21
Oct 01~05	17.05	13.70	18.55	12.31	21.56	8.79	20.97	16.33	13.27	11.19
Oct 06~10	8.70	6.99	9.47	6.29	11.00	4.49	10.70	8.33	6.77	5.71
Oct 11~15	15.53	12.49	16.91	11.21	19.65	8.01	19.11	14.88	12.09	10.20
Oct 16~20	24.36	19.58	26.51	17.59	30.81	12.56	29.97	23.33	18.97	16.00
Oct 21~25	21.55	17.32	23.46	15.56	27.25	11.11	26.51	20.64	16.77	14.15
Oct 26~31	8.94	7.18	9.73	6.45	11.30	4.61	10.99	8.56	6.96	5.87
Nov 01~05	3.07	2.35	2.03	1.77	1.83	2.20	2.22	3.71	2.59	4.68
Nov 06~10	5.11	3.92	3.39	2.95	3.05	3.66	3.69	6.18	4.31	7.79
Nov 11~15	2.16	1.66	1.43	1.25	1.29	1.56	1.56	2.62	1.83	3.31
Nov 16~20	3.83	2.94	2.54	2.21	2.28	2.75	2.76	4.64	3.23	5.84
Nov 21~25	4.08	3.13	2.70	2.35	2.43	2.93	2.95	4.94	3.44	6.22
Nov 26~30	1.82	1.40	1.21	1.06	1.09	1.31	1.32	2.21	1.54	2.79
Dec 01~05	2.74	2.47	2.81	2.30	2.58	2.98	3.16	2.66	3.14	2.84
Dec 06~10	3.25	2.92	3.33	2.72	3.05	3.53	3.73	3.15	3.71	3.37
Dec 11~15	1.96	1.76	2.01	1.64	1.84	2.13	2.26	1.90	2.24	2.03
Dec 16~20	1.81	1.63	1.86	1.52	1.70	1.97	2.08	1.75	2.07	1.88
Dec 21~25	1.30	1.16	1.33	1.09	1.21	1.41	1.49	1.25	1.48	1.34
Dec 26~31	1.18	1.06	1.21	0.99	1.12	1.29	1.36	1.15	1.36	1.23



The Study on Water Supply System for Siem Reap Region in Cambodia	**Figure 5.1.2 Estimated 10-year Flow Hydrograph at French Weir (5-day Flow)**
Japan International Cooperation Agency	

Consequently, the intake site is recommended to be located in the reaches between the military compound and the Angkor Bridge from hydrological viewpoint. The ground levels are approximately EL. 17 and 20 m, respectively (refer to Figure 2.2.4). In general, the slope of 1~3 $^{0/00}$ is required for the piped gravity water supply and accordingly it might be difficult to convey the raw water by gravity to the town center (approx. EL. 13 m). Same figure of water yield can be applied in this stretch, since no tributary joins and the catchment area is practically the same.

(3) Water Yield

No regulation exists on water use right for the West Baray, the Siem Reap River or the Lake Tonle Sap at present. There is no plan to make one in the near future. Accordingly, the possible water yield from the river is estimated taking into account the methodology widely applied in Japan:

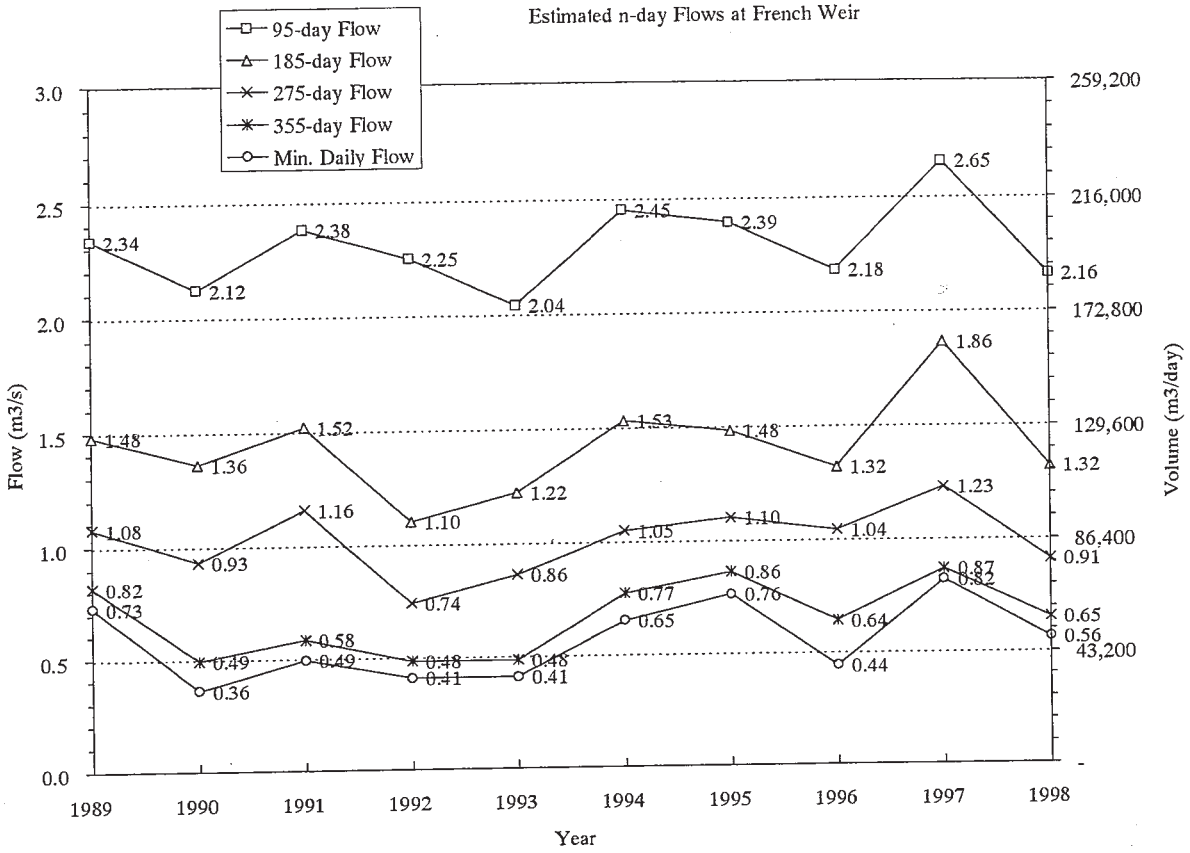
Possible water yield=10-year drought flow - Maintenance flow - Vested water use

1) 10-year Drought Flow

The n-day flows of the Siem Reap River at the French Weir is estimated for 10 years as shown in Figure 5.1.3 based on the generated 10-year daily hydrograph. The 10-year drought discharge (minimum 355-day flow/10 years) is assumed to be 0.48 m^3/s at the French Weir. There is no flow on the Canal A in the driest season at present because of the reasons already mentioned in section 2. Therefore, this value is purely 10-year drought flow of the Siem Reap River. The 2nd and 3rd minimum drought flow is assumed 0.48 m^3/s and 0.49 m^3/s, respectively.

2) Maintenance Flow

There is no regulation on the maintenance flow of the Siem Reap River. However, it is necessary to maintain a certain amount of water for conservation of the natural river environment. Therefore, the maintenance flow at the weir is assumed here equivalent to the estimated 10-year minimum daily flow at 0.36 m^3/s in year 1990 pattern (refer to Figure 5.1.3).



unit: m3/s

Year	n-day Flow				
	95-day	185-day	275-day	355-day	365-day
1989	2.34	1.48	1.08	0.82	0.73
1990	2.12	1.36	0.93	0.49	0.36
1991	2.38	1.52	1.16	0.58	0.49
1992	2.25	1.10	0.74	0.48	0.41
1993	2.04	1.22	0.86	0.48	0.41
1994	2.45	1.53	1.05	0.77	0.65
1995	2.39	1.48	1.10	0.86	0.76
1996	2.18	1.32	1.04	0.64	0.44
1997	2.65	1.86	1.23	0.87	0.82
1998	2.16	1.32	0.91	0.65	0.56
Min.	2.04	1.10	0.74	0.48	0.36
Max.	2.65	1.86	1.23	0.87	0.82
Ave.	2.30	1.42	1.01	0.66	0.56

The Study on Water Supply System for Siem Reap Region in Cambodia

Japan International Cooperation Agency

Figure 5.1.3
Estimated n-day Flows of Siem Reap River

3) Vested Water Use

There is no water use right along the Siem Reap River at present, however, the river water has been utilized mainly for the Crocodile Weir Irrigation System. The intake amount is approximately 1.0 m^3/s in average (refer to Figure 2.5.1). It is necessary to respect this vested intake amount, the Siem Reap flow can not satisfy this amount in the driest season in reality, though.

Some irrigation area spread also in lower reaches of the Crocodile Weir. The Hydrology Office supplies river water by opening the gate of the weir according to farmer's request. When the gate is opened, the supply to the Crocodile Weir Irrigation System decreases according to the fall of the water level at the weir. The weir can not satisfy the irrigation water supply at upper and lower reaches at the same time in the driest period.

Consequently, it is judged reasonable that the vested water use be assumed to be 1.0 m^3/s.

4) Possible Water Yield

The possible water yield from the Siem Reap River is summarized as shown below:

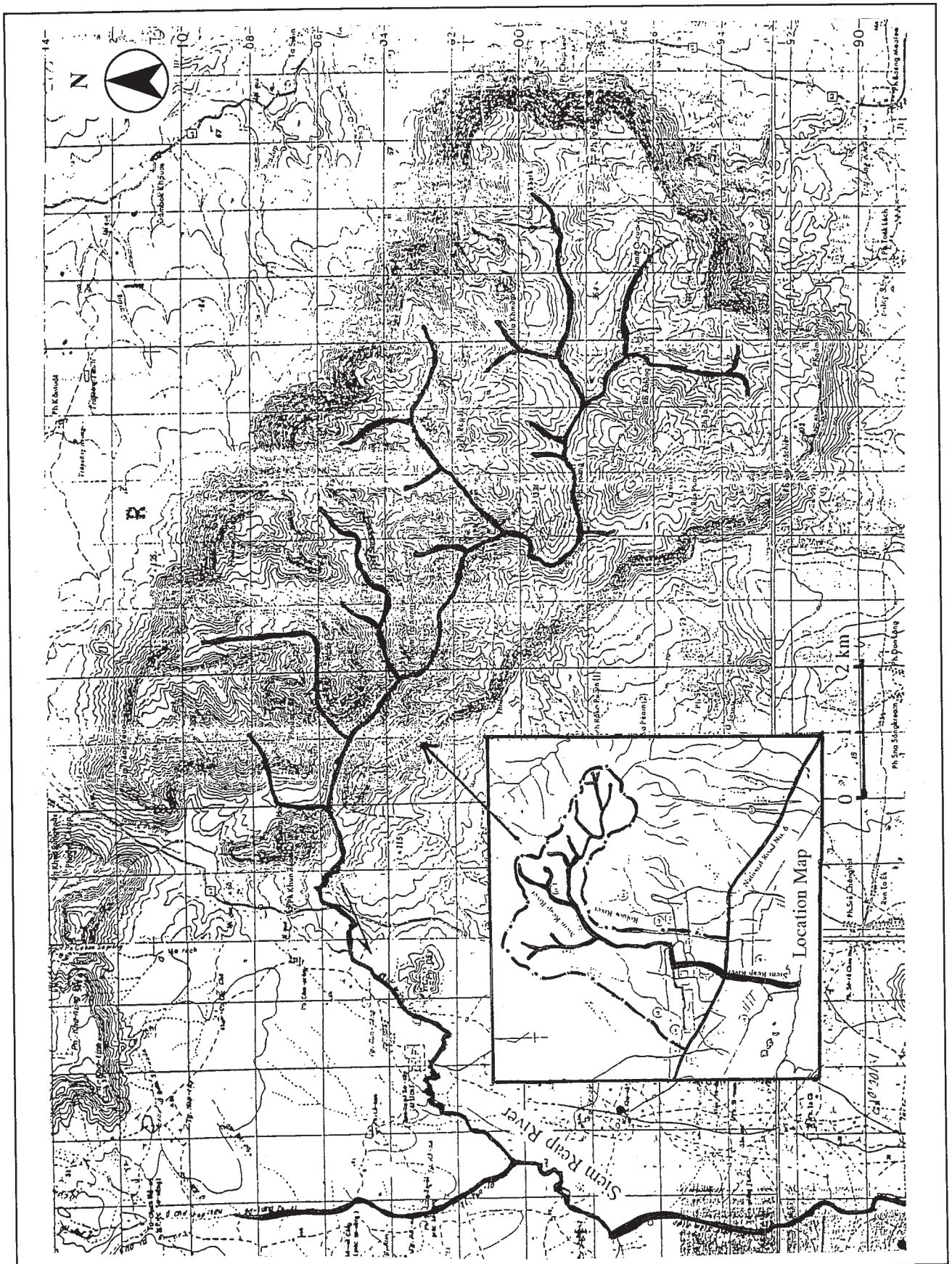
Possible Water Yield from Siem Reap River

	French Weir (A=500 km^2)	Angkor Bridge (A=525 km^2)
10-year drought flow (1)	0.48	0.50 (0.48*1.05)
Maintenance flow (2)	0.36	0.38 (0.36*1.05)
Vested water use (3)	1.00	1.00
Possible water yield (1) - (2) -(3)	-0.88	-0.88

The possible yield becomes 0 m^3/s and accordingly the Siem Reap River option (with no dam) can be completely discarded form surface water source alternatives.

(4) Preliminary Consideration of a Dam in Kulen Mountains

The topography around the Kulen Mountains located in upper reaches of the Siem Reap River is shown in Figure 5.1.4. The ideas of the dam in the mountain presented in some previous studies were limited to the conceptual one with no quantitative basis. Under the threatening security condition in the Kulen Mountain lasting even in 1999, it is practically impossible to carry out field reconnaissance in the mountains. Therefore, the investigation on the dam has to be carried out by deskwork only so far.



The Study on Water Supply System for Siem Reap Region in Cambodia	**Figure 5.1.4 Topography around Kulen Mountains**
Japan International Cooperation Agency	

As for water supply, the dam option does not seem a profitable surface water alternative. The reasons are as follows:

- The Siem Reap River already has a big adjustment of flow regime in lower reaches, namely, the West Baray and the reservoir is able to store around a half of total runoff of the Siem Reap River (refer to Table 5.2.1); sequential dam arrangement might not work effectively; and
- There is high possibility that the West Baray would be able to produce the surplus yield for water supply sufficiently as described in succeeding section 5.

The location of dam axis will be investigated in Phase II (Master Plan) based on the geological information. Water balance analysis might be conducted as the occasion demands to decide the dam capacity by using the water demand in 2010 to be investigated and 10-year flow regime.

5.2 West Baray

(1) Available Intake Site

It will be necessary to introduce the integrated reservoir operation rule for irrigation and water supply in order to utilize the reservoir water effectively. Consequently, the intake site is recommended to be located at the existing outlet structure. The ground elevation at the outlet is approximately 16 m so it is impossible to convey the raw water by gravity to the town center.

(2) Water Yield

The potential inflow capacity from the Siem Reap River to the West Baray is shown in Table 5.2.1. The potential is estimated on the assumption that the flow above 1.4~2.0 m^3/s (maintenance flow + vested water use) and below 14 m^3/s (flow capacity of Canal A) is diverted to the reservoir at the French Weir. A year considered here is from June to May of the next year to include a cycle of the reservoir level variation. The minimum capacity is estimated to be 34.1 million m^3 (1.4 m^3/s<Q<14 m^3/s) in 1992-1993 pattern.

The potential capacity of the reservoir is shown in Table 5.2.2 and Figure 5.2.1. The potential is estimated under the condition that the storage consists of 1) the inflow between 1.4 m^3/s and 14 m^3/s from the Siem Reap River and 2) the storage by rainfall - loss by evaporation. The average potential inflow capacity is an estimated 45.8 million m^3, which is equivalent to around half the average total Siem Reap flow of 90.9 million m^3.

Table 5.2.1 Potential Inflow Capacity to West Baray Reservoir

unit: 10^6 m^3

Year (Jun - May)	Potential capacity to be straged in WBR (M+V)<Q<*14 m^3/s				
	Maintenance flow + Vested water use at Crocodile Weir (M+V)				
	1.2	1.4	1.6	1.8	2.0
1989 - 1990	52.0	48.5	45.9	43.5	41.5
1990 - 1991	46.1	42.6	39.7	37.3	35.5
1991 - 1992	54.3	51.3	48.8	46.6	44.6
1992 - 1993	**36.8**	**34.1**	**31.9**	29.9	28.1
1993 - 1994	50.4	47.3	44.6	42.3	40.4
1994 - 1995	38.8	35.0	32.0	**29.5**	**27.1**
1995 - 1996	57.3	53.8	51.1	48.8	46.8
1996 - 1997	55.7	52.0	48.5	45.4	42.8
1997 - 1998	51.0	47.3	44.1	41.5	39.2
1998 - 1999	(47.6)	(44.9)	(42.6)	(40.2)	(38.1)
Ave.	49.0	45.7	42.9	40.5	38.4
Min.	36.8	34.1	31.9	29.5	27.1
Max.	57.3	53.8	51.1	48.8	46.8

Note: Flow capacity of Canal A (French Weir - Reservoir) is estimated 14 m^3/s.

Table 5.2.2 Potential Capacity of West Baray Reservoir

Period (Jun- May)	Total Volume of Siem Reap River (Before Frech Weir) (10^6 m^3)	Flow to Siem Reap River (After Frech Weir) Q<1.4, 14<Q (10^6 m^3)	Potential Inflow Capacity from Siem Reap River 1.4<Q<14 (A) (10^6 m^3)	Storage by Rainfall (July - May)					Potential Capacity (E) (A)+(D) (10^6 m^3)	Estimated Maximum Water Use for Irrigation <year 1998> (F) (10^6 m^3)	Remainder of Capacity (E)-(F) (10^6 m^3)
				Rainfall		Lake Evaporation		Difference (D) (B)-(C) (10^6 m^3)			
				(mm)	(B) (10^6 m^3)	(mm)	(C) (10^6 m^3)				
Jun '89 - May '90	94.83	46.34	48.49	1514.5	23.57	1079.3	10.79	12.78	61.27	36.02	25.25
Jun '90 - May '91	82.48	39.88	42.60	1198.7	18.65	1079.3	10.79	7.86	50.46	36.02	14.44
Jun '91 - May '92	99.04	47.76	51.28	1596.6	24.84	1079.3	10.79	14.05	65.33	36.02	29.31
Jun '92 - May '93	70.01	35.88	**34.13**	1115.8	17.36	1079.3	10.79	6.57	**40.70**	36.02	**4.68**
Jun '93 - May '94	101.92	54.61	47.31	1656.2	25.77	1079.3	10.79	14.98	62.29	36.02	26.27
Jun '94 - May '95	75.00	40.00	35.00	1235.2	19.22	1079.3	10.79	8.43	43.43	36.02	7.41
Jun '95 - May '96	108.95	55.11	53.84	1802.1	28.04	1079.3	10.79	17.25	71.09	36.02	35.07
Jun '96 - May '97	97.41	45.40	52.01	1517.9	23.62	1079.3	10.79	12.83	64.84	36.02	28.82
Jun '97 - May '98	88.16	40.87	47.29	1323.0	20.59	1079.3	10.79	9.80	57.09	36.02	21.07
Jun '98 - May '99	-	-	(44.93)	-	-	1079.3	10.79	-	(44.93)	36.02	8.91
Average	90.87	45.09	45.77	1440.0	22.41	1079.3	10.79	11.62	56.14	-	20.12
Min.	70.01	35.88	34.13	1115.8	17.36	1079.3	10.79	6.57	40.70	-	4.68
Max.	108.95	55.11	53.84	1802.1	28.04	1079.3	10.79	17.25	71.09	-	35.07

Note: Reading of 25.0 m (at the outlet) = approx. 19.6 m, MSL (Difference = 5.4 m)

Vol.max <Capacity at max. water stage (19.6 m, MSL)> = 48.8 (10^6 m^3)

Vol.min <Capacity at min. water stage (12.6 m, MSL)> = 0.2 (10^6 m^3)

Effective capacity = 48.6 (10^6 m^3)

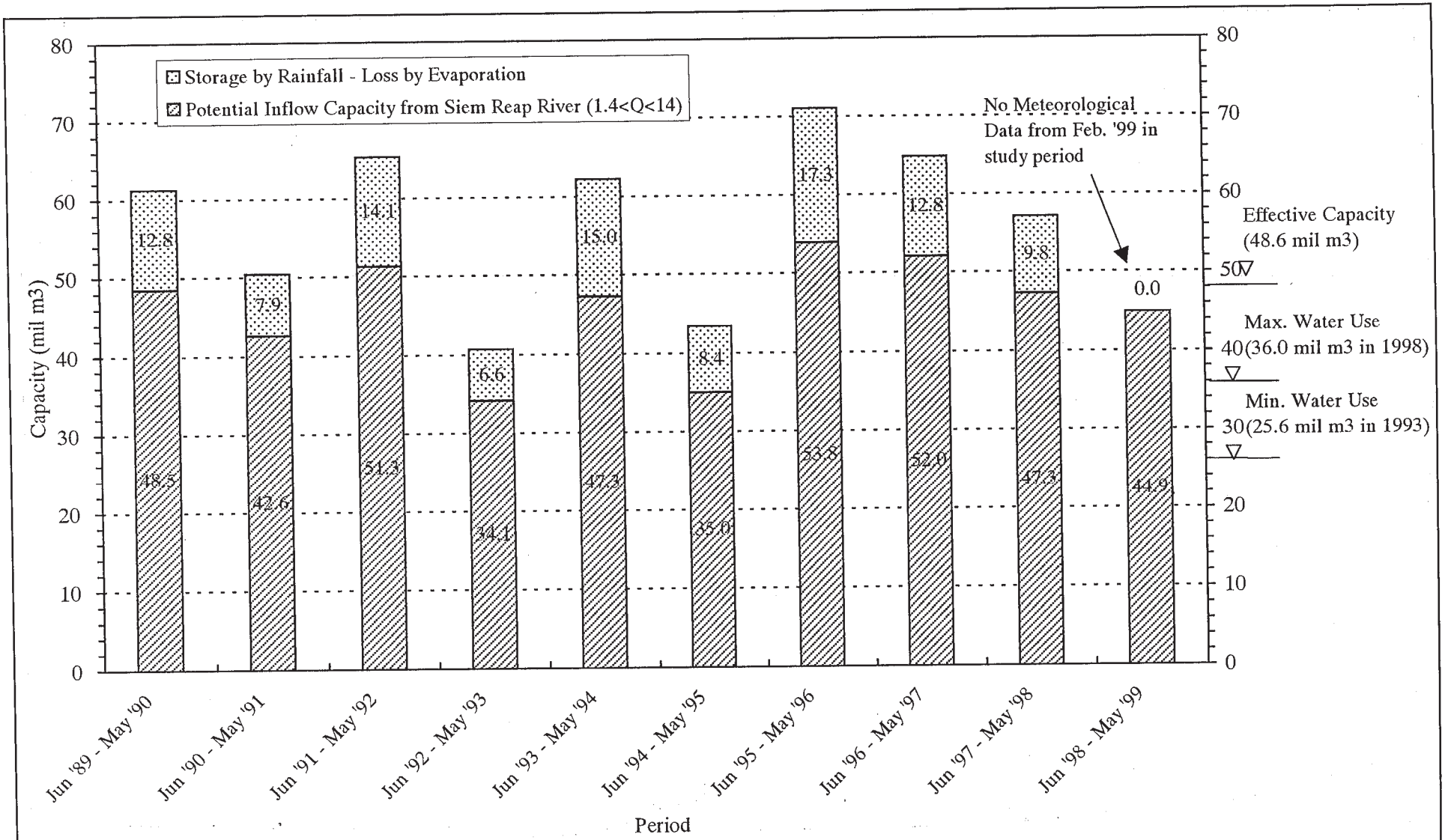
Total reservoir area = 15.56 (km^2)

Approx. max. total area of water surface = 10 (km^2)

Er= 0.7 *Ep

where; Er: Lake Evaporation

Ep: Pan Evaporation



The Study on Water Supply System for Siem Reap Region in Cambodia

Japan International Cooperation Agency

Figure 5.2.1
Potential Capacity of West Baray Reservoir

The minimum potential capacity is an estimated 40.7 million m^3 in 1992-1993 pattern (34.1 million m^3: inflow, 6.6 million m^3: storage by rainfall). The remainder will still be 4.7 million m^3 even if the maximum use of 36 million m^3 in 1998 is subtracted from 40.7 million m^3. The remainder even equals the water supply of 16,600 m^3/day for 9.2 months. Therefore, surplus water yield can be expected by the effective integrated reservoir operation based on carry over storage.

The reservoir is currently used exclusively as an irrigation water source. So the integrated operation rule shall be established in close cooperation with MOA.

It will be most preferable that the surplus water yield for water supply be produced only by the coordination with MOA based on the integrated reservoir operation. However, according to circumstances, it might be necessary to secure additional reservoir capacity for the dry season (8 months) by the following methods in addition to the integrated operation:

- Excavation in the eastern part of the reservoir (around 4.0 million m^3): or
- Increment of capacity by maximum rise of water level up to EL. 19.9 m (25.3 m, reading) on condition that the West Mebon be preserved (around 4.3 million m^3).

In any alternatives, it is essential to rehabilitate the French Weir, American and Takav Gates, and the reservoir ring dyke to facilitate the reservoir effectively.

It is essential to block the deteriorated portion of the French Weir sluice to divert the river flow to the reservoir effectively when the flow is more than 1.4 m^3/s (maintenance flow + vested water use). However, the sluice should be opened to secure a certain amount of river flow in the lower reaches of the river when the flow is less than 1.4 m^3/s in the dry season. Ironically enough, the present deteriorated portion at the weir has functioned just as if no gate discharging and has preserved the low flow of the Siem Reap River in lower reaches.

Water balance calculation shall be carried out in Phase II (Master Plan) by using the following factors to confirm the availability of the reservoir in detail:

- Water demand in 2010 to be investigated;
- 5-day flow regime at the French Weir for 10 years (refer to Table 5.1.2);
- Integrated reservoir and gate operation rule to be decided; and
- Meteorological factors.

5.3 Lake Tonle Sap

(1) Available Intake Site

From a hydrological viewpoint, the intake site should be located below approximately EL. 0.7 m, which is 20-year return period minimum water level in the dry season (refer to section 4). A 20-year return period was used as it was suggested by Mekong Secretariat Report. Therefore, the available intake site is recommended to be located at least 4 km offshore from the existing harbor, the shoreline at the lowest level. The distance from the town center will exceed 19 km. It is naturally impossible to convey the raw water by gravity to the town center.

(2) Water Yield

Lake Tonle Sap is the largest permanent freshwater lake in Southeast Asia and its storage is more than 1,300 million m^3 even at the lowest water level below EL. 1 m at the end of the dry season. The possible yield from the lake can be considered practically as unlimited.

5.4 Hydrological Evaluation of Alternative Source of Surface Water

The overall hydrological evaluation of surface water source alternatives is summarized in Table 5.3.1 based on the considerations mentioned above. A conclusion is that the West Baray option is proposed as the most preferable alternative in view of the water yield as well as water quality.

6. Recommendations

It is essential that the hydrometry in the Study Area will be continued and data accumulated by MOA without interruption. The accumulated data will be the important basis for any kind of study to be conducted in future. The hydrometry schedule is tentatively proposed as follows:

Table 5.3.1 Hydrological Evaluation of Surface Water Source Alternatives

No.	Surface Water Source	No.	Alternatives	Possible Water Yield for Water Supply				Available Intake Site				Water Quality	Remarks	Evaluation
				V Volume (10^6 m^3)	v Volume (m^3/d)	Q Flow (m^3/s)	T Supply Period (month) (water demand assumed to be 16,600 m3/d)	Proposed Location	Elevation (m, MSL) City Center = EL. 13 m	Distance from City Center (bridge on N.R. 6) (km)	Gravity conveyance by pipeline			
1	Siem Reap River	1-1	No dam	0.0	0.0	0.0 (0.48-0.36-1.0 = -0.89)	0	Reaches between the north edge of military compound and Angkor bridge (to be located upstream of backwater by Crocodile Weir)	Approx. 17~20 (ground level)	3.5~6.5 (along river course)	△	△	*0.48 m3/s: drought (355-day) flow (minimum/10 years) *0.36 m3/s: maintenance flow (min. daily flow/10 years) *1.0 m3/s: average vested water use for irrigation by Crocodile Weir System	×
		1-2	Dam in Kulen Mountains	4.0<V	16,600<v	0.19<Q	8 (8: Supply by Dam 4: Surplus water of river)						*It is difficult to enter the mountains due to current security problem. *Some heritage might be founded. *Effect of dam regulation seems not so big.	△
2	West Baray Reservoir	2-1	Excavation (approx. 4.0 mil m3 for 8 months in the dry season)	4.7<V	16,600<v	0.19<Q	9.2<T	Existing outlet structure	Approx. 16 (ground level around outlet)	11	×	○	*40.7 mil m3 (min. potential capacity <minimum/10 years>) - 36 mil m3 (max. water use in 1998) = 4.7 mil m3 *Yield more than 4.7 mil m3 can be produced by carry over storage based on integrated reservoir operation.	○
		2-2	Coordination of water use with MOA										*Water balance calculation is required to determine maximum yield.	◎
		2-3	Max. rise of water stage up to 19.9 m (19.6 m, MSL <25.0 m, reading> + 0.3 m)										*Increment of 0.3 m is determined based on the elevation of West Mebon. *Volume increment is 4.3 mil m3.	○
3	Lake Tonle Sap	3-1	-	Unlimited			12	4 km offshore from existing harbor	0.7 (minimum water stage in dry season)	19	×	×	(cf.) Max. water stage is around 10 m in rainy season.	×

Schedule of Hydrometry in Siem Reap Region

No.	Location	Staff Gauge Reading		Flow Measurement	
			Interval		Interval
1	French Weir	Yes	1 month	No	-
2	Prasat Keo	Yes	Everyday (7:00 and 19:00)	Yes	1 month
3	Angkor Bridge	Yes	1 month	Yes	2 month
4	Takav Gate	No	-	Yes	1 month
5	UNTAC Bridge	Yes	Everyday (7:00 and 19:00)	No	-
6	West Baray	Yes	Everyday (7:00)	No	-
7	WBR Canal-2, 3 and 8	No	-	Yes	1 month
8	Vichear Chin Canal	No	-	Yes	1 month
9	Chreav Canal	No	-	Yes	1 month

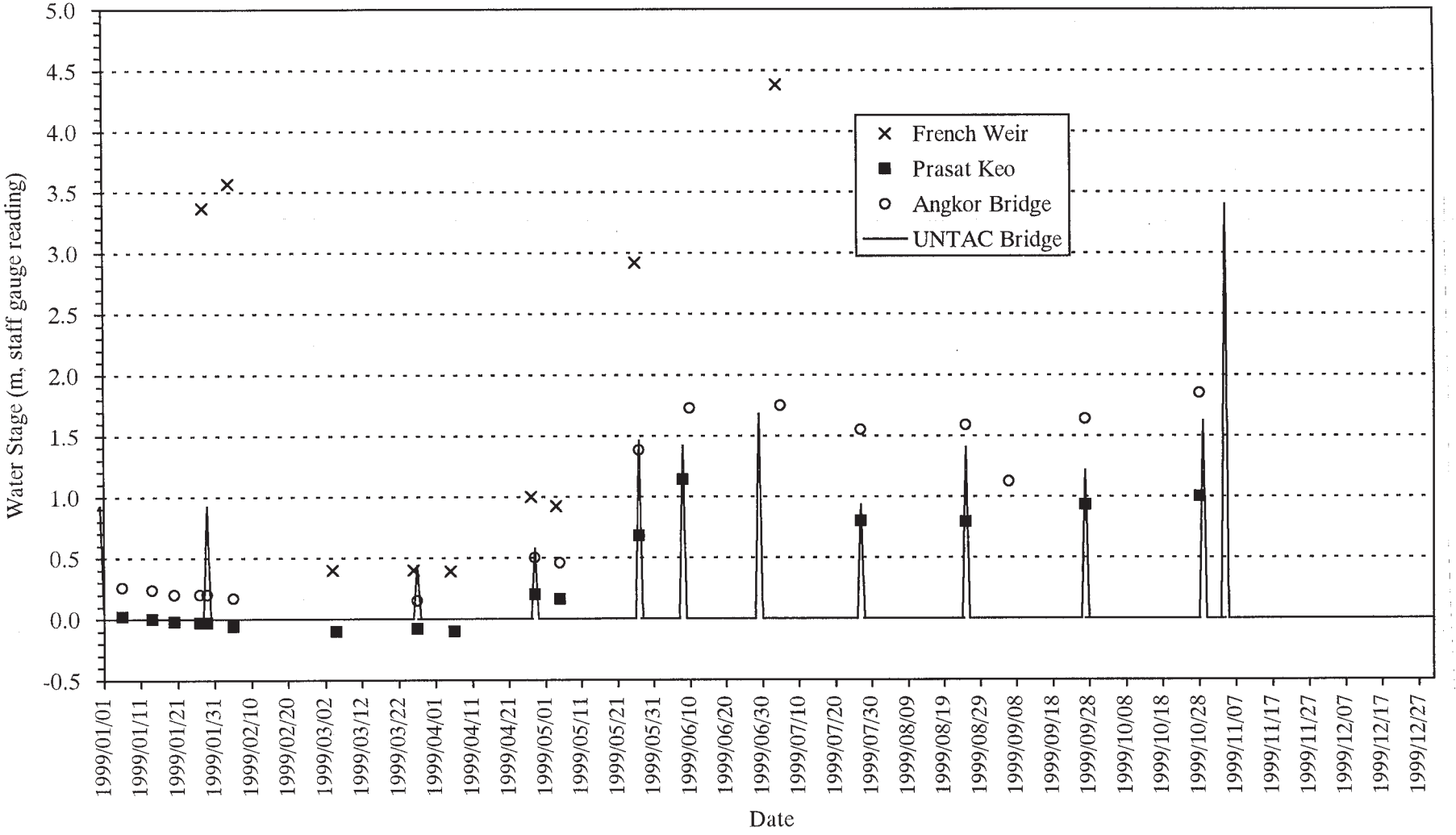
The most important items flow among those above are as follows:

1) Daily water level at Prasat Keo;
2) Periodical flow measurements at Prasat Keo; and
3) Daily water level of the West Baray.

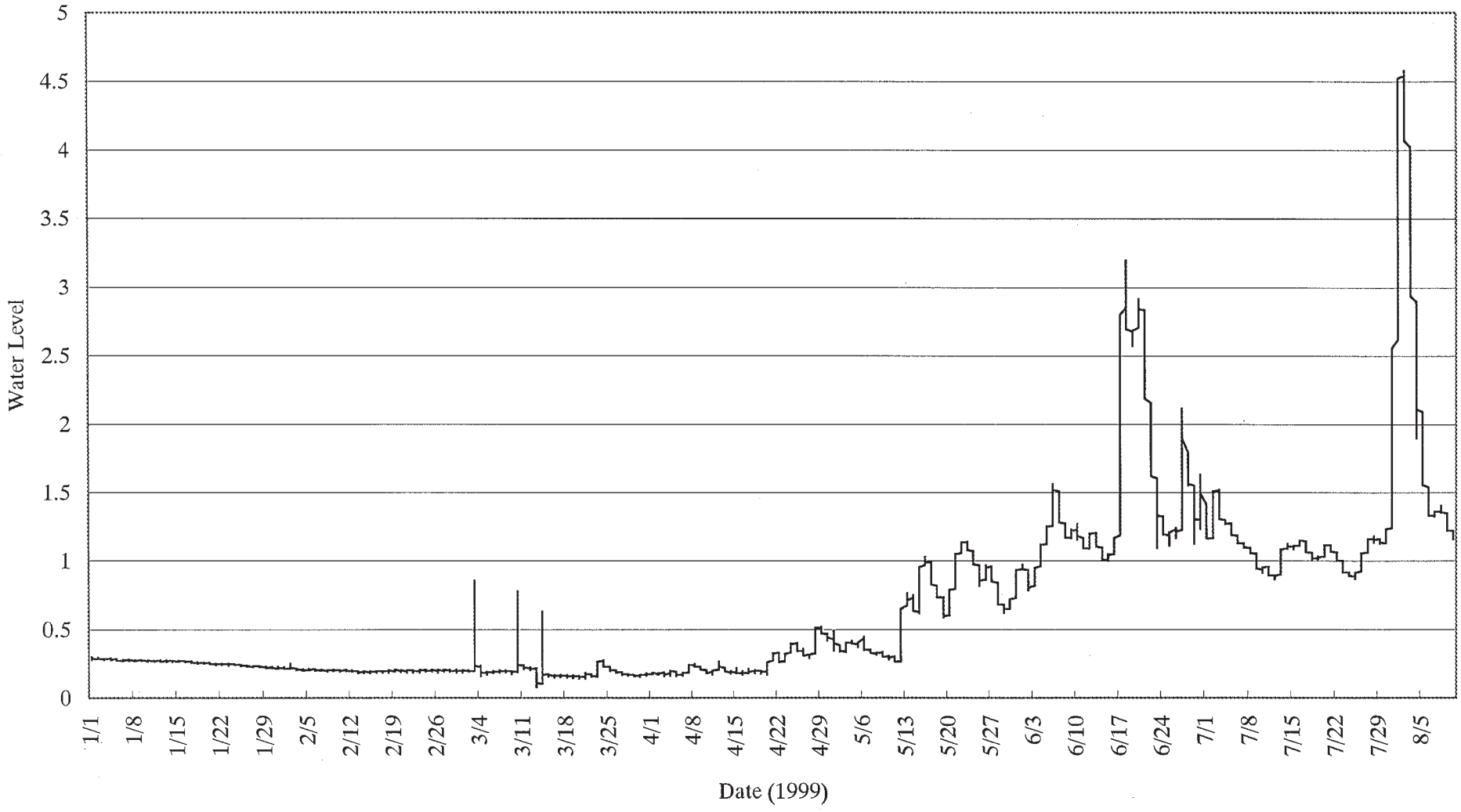
It is also recommended that an automatic rainfall gauge be installed in the Kulen Mountains to supplement the only existing gauge at Siem Reap Airport after the security problem in the mountains is improved in future.

7. Additional Data

In continuation of this study, additional data is compiled up to November 1999. These are presented in Figure 7.1 and Figure 7.2.



The Study on Water Supply System for Siem Reap Region in Cambodia	**Figure 7.1** Manual Observation of Water Stage of Siem Reap River
Japan International Cooperation Agency	



The Study on Water Supply System for Siem Reap Region in Cambodia	**Figure 7.2 Automatic Observation of Water Stage of Siem Reap River**
Japan International Cooperation Agency	

8. References

1) Angkor Foundation, Budapest - Hungary (June 1993) “Water Management in the Angkor Area”. Ferene GARAMI & Dr. Istvan KERTAI.

2) Mekong Secretariat (October 1993) “Development Plan for Tonle Sap and Chakdomuk, Phase I, Final Report”, Orstom in association with BCEOM.

3) Mekong Secretariat (June 1994) “Irrigation Rehabilitation Study in Cambodia, Final Report, Annex A - Hydrology”. Sir William Harcrow & Partners Ltd. in association with Mandala Agricultural Development Corporation.

4) APSARA (November 1995) “Ville de Siem Reap - Angkor, Plan D’urbanisme de Reference et Projets Prioritaires, Volume I - III, Rapport Definitif”. CFD, ARTE & BCEOM.

5) Ministry of Agriculture and Fisheries (May 1997) “Review of the Hydrology Sector in Cambodia, Prepared for the Project: CMB\95\003, Natural Resources - Based Development Strategy for the Tonle Sap Area”. Tes Sopharith.