SECTOR B

PREPARATORY STUDY FOR PILOT WORKS

THE STUDY ON MEKONG RIVERBANK PROTECTION AROUND VIENTIANE MUNICIPALITY IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC

FINAL REPORT
VOLUME 4
-SUPPORTING REPORT-

SECTOR B

PREPARATORY STUDY FOR PILOT WORKS

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SECTOR B

PREPARATORY STUDY FOR PILOT WORKS

This Sector B compiles all the process and result of the formulation of the Preparation Study for Pilot Works around Vientiane City conducted during the 1st Work in Lao P.D.R. from December 2001 to March 2002.

1 BASIC PRINCIPLES FOR PILOT WORKS

Pilot riverbank protection works in the Study Area will be executed by the Study Team in 2nd Work in Lao P.D.R. to establish sustainable bank protection works in Lao P.D.R.

The Study Team will introduce traditional river works of Japan to implement pilot works. These works are expected to conserve and create favorable river environment and to be sustainable and low cost as well. At each work site, changes of river flows, changes in river channel and riverbed are monitored surveying them periodically. Results of the pilot works and their monitoring will also be s basic data for a bank protection master plan to be formulated in 3rd Work in Lao P.D.R., which technically directs the bank protection activities by GOL.

Pilot works will be executed under the technical guidance and supervision of the Study Team. These works will clarify the effectiveness and problems of the traditional works of Japan and the technology necessary for the Laotian engineers to carry out the work by themselves will be transferred effectively with practice.

Infrastructure Development Institute (IDI) of Japan conducted bank protection test works at Sibounheuang applying Soda Mattress Works, a traditional river works of Japan. The work has completed and is being monitored now. These test works shall be succeeded and developed by the pilot works.

2 SELECTION OF SITES FOR PILOT WORKS

Field reconnaissance was made for the Mekong River around Vientiane City both from land and river during the period from December 14 to December 22, 2001. The reconnaissance were made more intensively especially at the existing riverbank protection work sites and other riverbanks in critical conditions including those identified by the Government of Lao P.D.R. These sites are shown in Figure 2.1.

For the selection of three pilot work sites, the conditions of these sites are summarized comparatively in Table 2.1. Excluding the riverbanks that are considered relatively stable due to their topographical situation and the existing bank protection works, the following five sites out of 19 sites were nominated for the pilot work sites:

Site No.3 : Ban Dongphosi
Site No.6 : Thakhek / Ban Hom
Site No.8 : Bo-O
Site No.9 : Wat Chom Cheng
Site No.17 : Sibounheuang

All of these sites need immediate bank protection works. However, taking the requirement as pilot work site and the permissible total work length into consideration, the following three sites are selected for the pilot works:

1) Ban Dongphosi site: This site requires immediate works to protect the important facilities and strengthen existing bank protection works at Friendship Bridge and Culture Park.
2) Sibounheuang site: Test works on the riverbank protection by using Japanese traditional works were implemented at this site by Infrastructure Development Institute (IDI-Japan), and the monitoring is now ongoing. In order to supplement and extend these efforts, the site should be selected for the pilot work.
3) Wat Chom Cheng site: Among the remaining three sites, Thakhek / Ban Hom and Bo O sites are deemed too large in scale for the present pilot work. Besides, the riverbank at the Wat Chom Cheng site shows different nature from other nominated riverbanks, namely, the riverbank does not form cliff though it is suffering from erosion. Pilot work at Wat Chom Cheng site would contribute to studying measures for this type.

Photos of present condition at three (3) selected sites during low water season on December 2001 are shown in Figure 2.2.

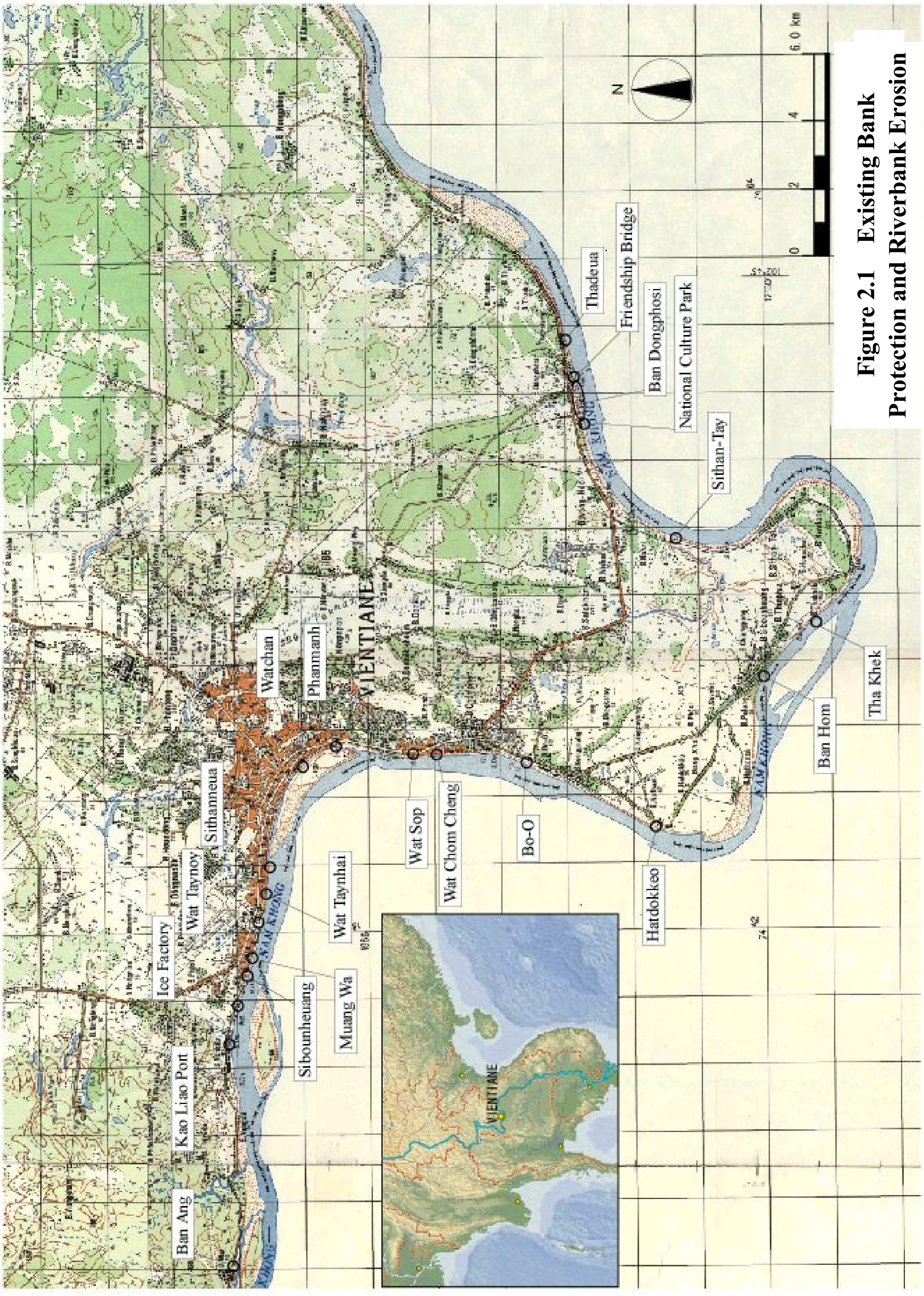

Figure 2.1 Existing Bank Protection and Riverbank Erosion

Table 2.1 (1/2) Selection of Sites for Pilot Works

Site No.	Site	Existing bank conditions	Activeness of erosion	Objects to be protected	Others matters to be noted	Nomination for pilot works
1.	Thadeua	Bank protected with gabion works.	Stable with protection works	Dike road	-	No
2.	Friendship Bridge	Bank protected with gabion works.	Stable with protection works	Bridge and dike road	The bank slope is now covered with sediment and vegetation.	No
3.	Ban Dongphosi	Riverbank forms cliffs	Active	Fuel company facilities	Protection works are necessary immediately to connect those of Friendship Bridge and Culture Park	**Nominated**
4.	National Culture Park	Bank protected with gabion works.	Stable with protection works	Culture park	-	No
5.	Nahai/ Sithan-Tai	Bank slopes are mild with some vegetation	Moderate	Farmlands on high water channel	-	No
6.	Tha Khek/ Ban Hom	Riverbank forms cliffs	Active	Villages and farm lands	Riverbank cliff continues for long distance.	**Nominated**
7.	Hatdokkeo	Bank protected with gabion works. Its upper end is damaged and short cliff bank exists at the lower end.	Moderate	Dike road and farmlands on high water channel	The bank protection work in this site may need adjustment / compensation for fish culturing and exploitation of gravel	No
8.	Bo-O	Riverbank forms cliffs.	Active	Farmlands and temple on high water channel.	DCTPC has a plan to protect the site.	**Nominated**
9.	Wat Chom Cheng	Riverbank collapsed without forming cliffs.	Active	Temple and yard of Wat Chom Cheng	A simple wooden pile work was constructed by the monks of temple.	**Nominated**
10.	Wat Sop	Bank protected with gabion works.	Stable with protection works	Dike road and temple	-	No
11.	Phanmanh	Bank protected with gabion works.	Stable with protection works	Dike road	-	No

(Cont'd)

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Table 2.1 (2/2) Selection of Sites for Pilot Works

Site No.	Site	Existing bank conditions	Activeness of erosion	Object to be protected	Others matters to be noted	Nomination for pilot works
12.	Wat Chan / Modern Home	Large scale land reclamation is under execution dredging the nearby riverbed.	Said getting active	Newly reclaimed housing lots and farmlands on the sand bar.	Large scale dredging and channel reform may change flood and sediment flows and cause riverbank erosion in downstream reaches.	No
13.	Sithanneua	Bank slope is collapsed probably due to embankment on riverbank slope.	Stable as a whole forming mild bank slope with some vegetation	Dike road	These damages should be prevented by encouragement of appropriate management of river facilities	No
14.	Wat Taynhai	A part of dike road is damaged.	Stable as a whole forming mild bank slope with some vegetation	Dike road	These damages to be repaired partly	No
15.	Wat Taynoy	Bank protected with gabion works.	Stable with protection works	Dike road	-	No
16.	Muang Wa	Bank protected with gabion works, though the central part were damaged in1999.	Stable with protection works	Dike road	-	No
17.	Sibounheuang	Riverbank forms cliff. The test works were conducted with gabions, soda- hurdle and soda-mattress works.	Active	Temple and yard of Wat Sibounheuang	The test works were conducted by IDI (Infrastructure Development Institute) - Japan. However, the work stretch is limited.	**Nominated**
18.	Ice Factory	Bank protected with gabion works.	Stable with protection works	Ice Factory yard	-	No
19.	Kao Liao port	Bank protected with cemented rocks.	Stable with protection works	Port facilities and yard	Bank protection works are combined with port facilities.	No
20	Ban Ang	Bank protected with gabion works	Stable with protection works	Dike road	-	No


Ban Dongphosi Site


Wat Chom Cheng Site

Sibounheuang Site

Figure 2.2 Present Condition at 3 Pilot Work Sites

3 SITE CONDITION

3.1 Outline of Topography and Geology

Roughly speaking, the Vientiane Plain, which is almost flat, has a right-angled triangle shape of 60km long base and 50km long height. The base of right-angled triangle is flanked with Mekong River. Nam Ngum River, a left tributary of Mekong River, reaches to the north of the Plain from the northern mountainous area, and runs meandering to the center of the Plain, and then changes its course to the east. Finally this river joins to Mekong River at the east-end of the Plain.

The geology of the Vientiane Plain is composed of Jurassic to Cretaceous sandstone and claystone at its base, which is overlain by the Glacier-age deposits of the Vientiane Gravel and recent river and marsh deposits.

According to the existing geological data in the Vientiane Plain, bedrocks lie at around 20~30m in depths below the Vientiane gravel. The Vientiane Gravel is widely distributed on the hilly areas surrounding the Plain.

Although the Vientiane Plain lies on the continental stable plate (Central Indochina Massif), the basement had been in the course of a gentle sinking after some tens of thousand years before, and in this time duration, the Vientiane Gravel deposited thickly as fan-deposits on the Plain. The deposits are said to be the river deposits from Himalayan by the Mekong in the Glacier Age. However, the Plain seems to be gradually eroded due to the uplift of Himalayan region by the Mekong, which always changes its course on the Plain by meandering. The recent changes of river course of Mekong River are read on an air-photograph or topographic map, as shown in Figure 2.6 of SECTOR A, which indicates that the present natural riverbanks are different in their geology by places.

The Vientiane Gravel, which is well consolidated when it is un-weathered, consists of well-rounded boulder and gravel (60~70%) with clay (30~40%). The average size of the rock materials is 5-10cm in diameter and the maximum is 20cm in diameter. They are composed of chart, quartzite, sandstone and green rock. The layer is covered by younger clay and silt layers, which are shown as more reddish in color when they are seemingly older in age.

3.2. Investigation of Riverbank

3.2.1 Types of Riverbank

From topographic and geological viewpoint, the riverbanks at 19 locations from Ban Ann (upstream) to Thadeua (downstream) were investigated. Based on the results, four (4) types of riverbanks could be identified. The schematic view of each type is as shown in Figure 3.1(1)-(4).

Type-1

Characteristics:

1)The sectional bank slope is 45° or less.

2)The surface of bank-slope is covered with present-time sand and silt. No original bank-slope, which is composed of clay layer, is observed due to the cover of younger deposits.

3)The younger deposits seem to be deposited and eroded in the wet season when water level is high, and they slid gradually downwards by decreasing of water level.

4)The slope surface is covered with vegetation and sometimes it is cultivated for vegetable to eat.
5)Basically, the riverbank is balanced in deposition and erosion.

Type-2

Characteristics:
1)The slope of riverbank is as steep as 65-90° .
2)No gentle sloped terrace is observed at the foot of the riverbank.
3)The clay layer in the steep slope shows spotted pale reddish yellow in color, and is well consolidated. Sometimes it has many small holes at the lower portion of the bank.
4)The upper layer of 1.5-2.0m in depths is dark colored weathered silt and clay, where the slope becomes somewhat gentle (50-60°).

Type-3

Characteristics:
1)Basically, the slope shape of riverbank is similar to Type-2, but weakly consolidated sand and gravel layer exists in the lower level of the slope where the layer is differentially scored to produce a hollow. Therefore, the upper portion over the hollow forms an overhanging clay block, behind which cracks develop. The clay block later falls down when water level is lowered.
2)The clay layer on the steep slope is pale reddish yellow in color, and has the same nature as that of Type-2.
3)The sharp difference between Type-2 and Type-3 is whether or not the weak layer exists at the foot on the slope

Type-4

Characteristics:
1)The slope consists of two parts, one is upper steep portion and the other is lower gentle portion.
The upper portion is pale yellowish brown in color and has a slightly weak consolidation than those of Type-2 and Type-3. This portion is eroded uniformly when water is high. The lower gentle portion is composed of the Vientiane Gravel that shows rather strong resistance against erosion owing to the consolidation of boulder and clayey matrix.
2)Between the upper clay layer and the lower Vientiane Gravel there is reddish sandy layer of 40-50cm in thickness.
3)The clear difference from other three types is the existence of the Vientiane Gravel at the foot of slope.

3.2.2 Relation between Type of Riverbank and Geology

As mentioned above, the investigated riverbanks at 19 locations can be classified into 4 types, while the previous river channels detected on air photos and topographical map are also taken into consideration, the following facts are indicated:

1) The clay layers on the riverbanks are somewhat different in its consolidation in places, indicating the time difference of deposition of the clay layers. The comparatively well-consolidated (stiff) clay layer shows in general more reddish color. The red color must indicate the weathering for a long time. The well-consolidated clay layer develops a few cracks and small holes in or on it. On the other hand, the younger clay layer shows pale yellowish gray in color and weaker consolidation. The youngest clay layer of top 1.0~2.0m thick shows dark brownish color owing to weathering and organic substances.
2) The riverbanks where the older clay layers are distributed might be the sections where the erosion by Mekong River was missed in recent time. The riverbanks from Kao Liao Port to Wat Taynhai, and around Bo O show Type-2 and Type-3. On the other hand, the section from Sithanneau to Chom Chen might be once eroded by the meandering Mekong River and recently might be filled with younger clay layers (yellow colored areas in Figure 3.2) indicating Type-1.
3) The riverbanks from Sithantai to Lao State Fuel Company and Thadeua are composed of moderately consolidated pale yellowish gray colored clay layers with the Vientiane Gravel at their foot. Those clay layers might be deposited in marshy or swampy areas after the river channel showing in blue color had changed to the present course.

3.2.3 Riverbank Type at Each Site

According to the above, riverbank type at each site for the pilot work falls into the following types:

- Ban Dongphosi site : Type 4
- Wat Chom Cheng site : Type 1
- Sibounheuang Site : Type 3

The characteristics of the riverbank type are taken into designing of bank protection works.

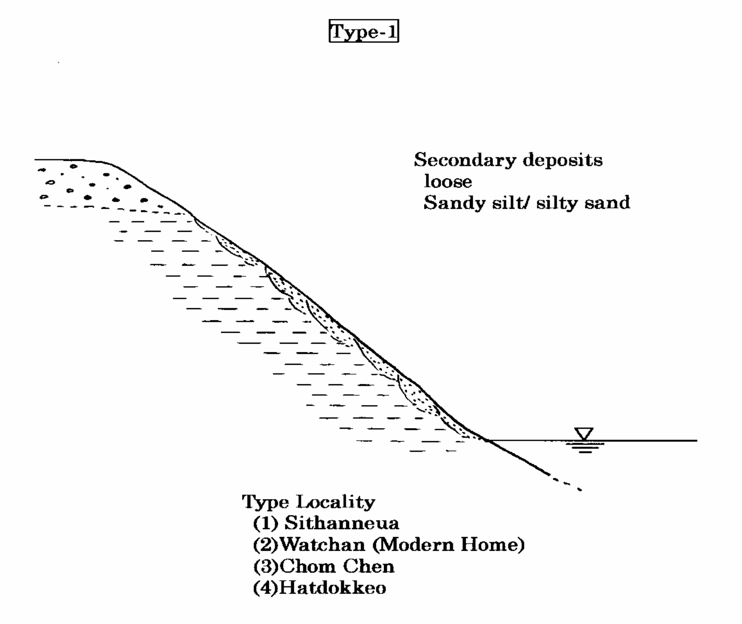

Figure 3.1 (1/4) Type of Riverbank

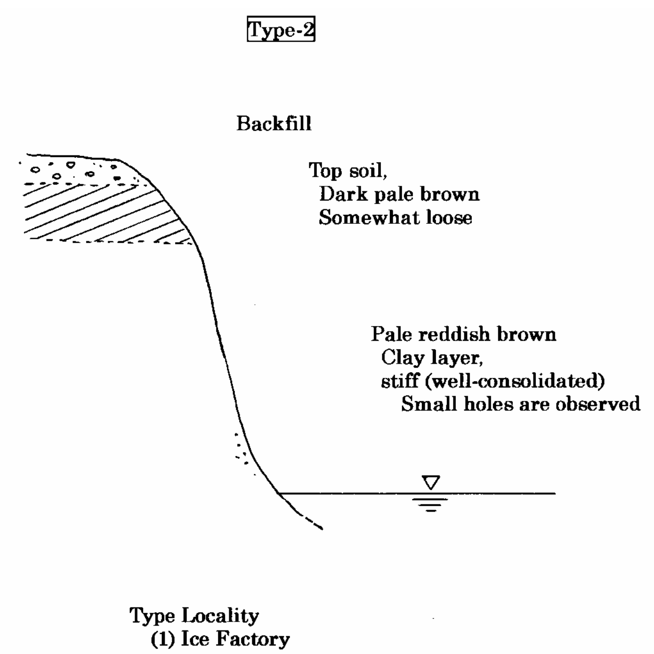

Figure 3.1 (2/4) Type of Riverbank

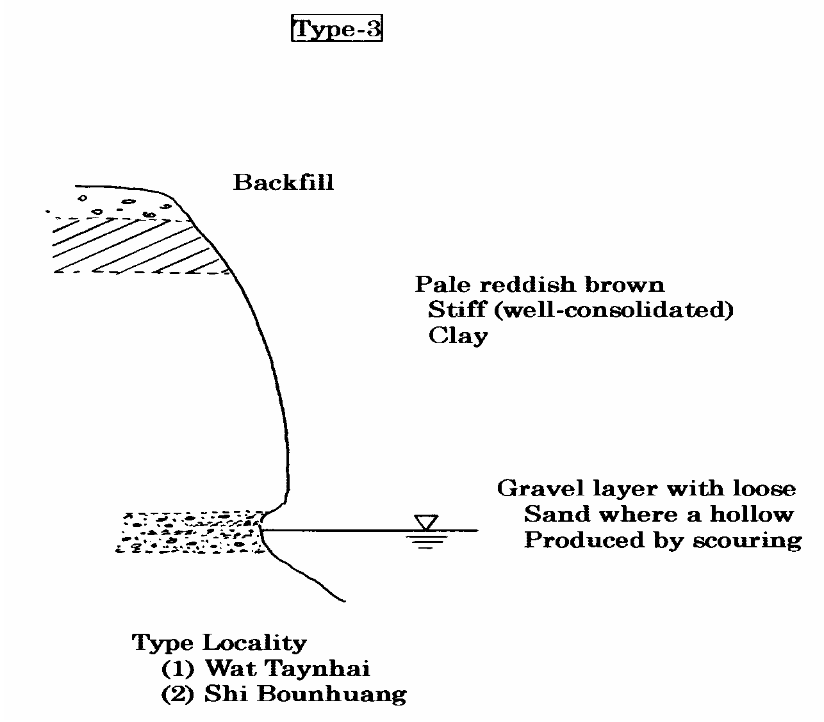

Figure 3.1(3/4) Type of Riverbank

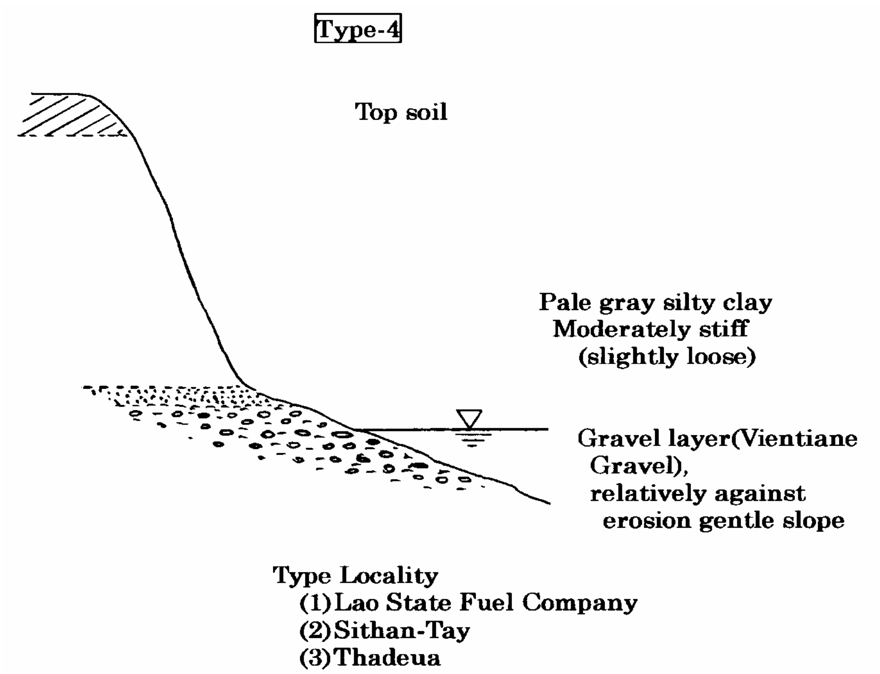

Figure 3.1(4/4) Type of Riverbank

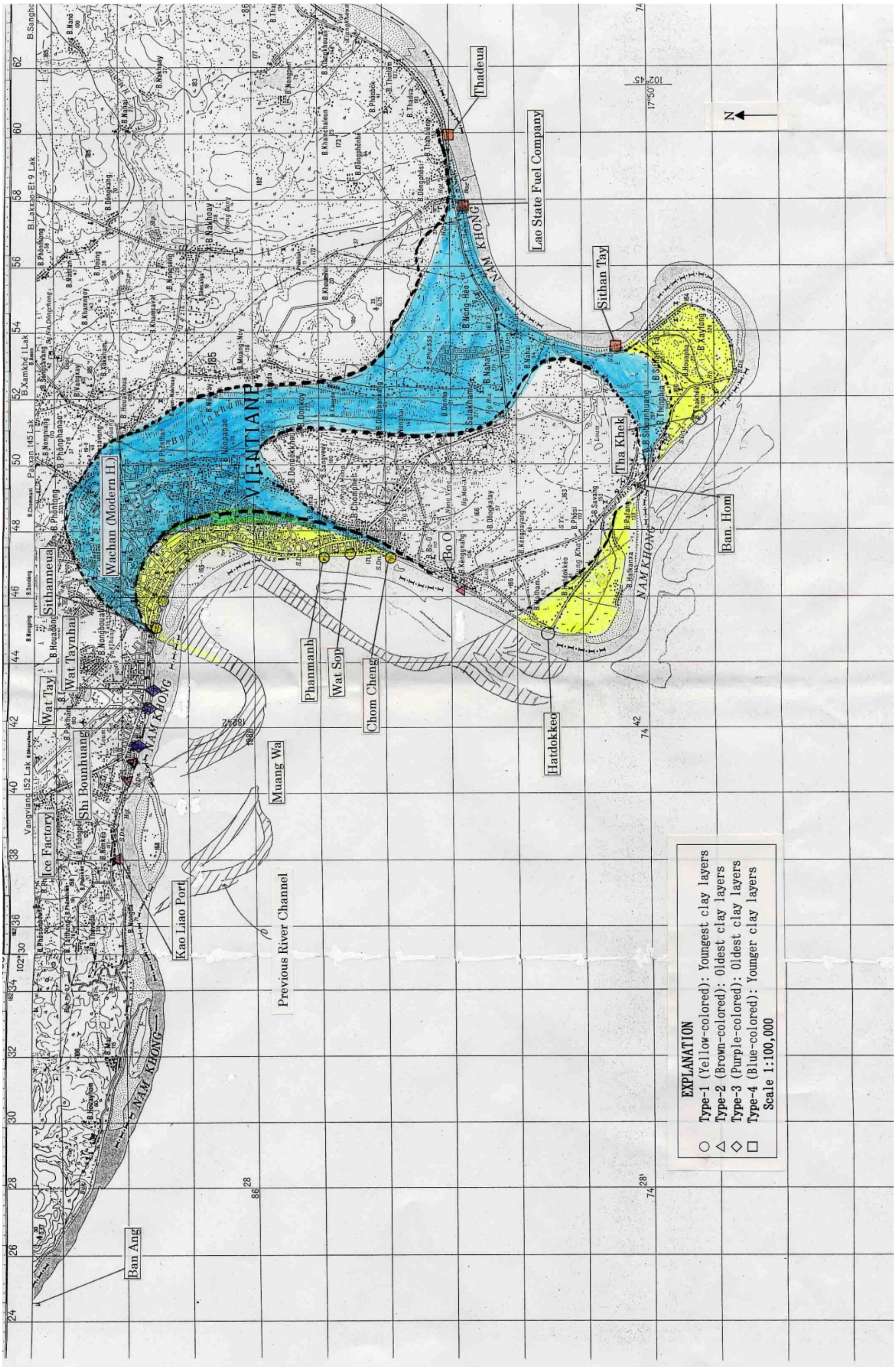

Figure 3.2 Type of Riverbank around Vientiane City

3.3 Design Flow Velocity

Here, the coefficient of roughness of Mekong River in the Vientiane neighborhood is first presumed by the non-uniform flow calculation under some conditions.
Next, the result of the flow velocity measurement executed by our study team in the vicinity of the riverbank at each site of pilot work and the section mean velocity obtained by the non-uniform flow calculation are compared, and velocity concentration ratio of the flow to the riverside part in each site is evaluated.
Afterwards, the design flow velocity of each bank protection work is evaluated as riverside part flow velocity at the flood by considering velocity concentration ratio and the section mean velocity at the discharge of the river channel brimmer of each pilot work site by the non-uniform flow calculation.

3.3.1 The Coefficient of Roughness 0f Mekong River

The non-uniform flow calculation was executed under some conditions intended for the region between 1548km and 1593km in Mekong River.
River channel section shape was read based on the plan of the river and the distribution of depth based on L.LWL, which had been recorded in it.
Uniform flow depth to the longitudinal slope of L.LWL (1/8,400) was calculated and the water level of the downstream edge was given.
Figure 3.3 shows the comparison of the rating curve of water level and discharge at Vientiane KM4 based on the field measurement and the non-uniform flow calculation result.
Manning's coefficient of roughness (n) of Mekong River in the Vientiane city neighborhood is evaluated as about 0.025 roughly according to this figure.
In addition, Figure 3.4 is a comparison of the rating curve evaluated by the flow velocity measurement result executed in the Sibounheuang Site neighborhood on August 28 and December 5, 2000 and the non-uniform flow calculation result.
It is understood that about 0.025 to 0.030 is appropriate as a value of coefficient of roughness (n) at this region by this figure.
Considering those two figures, the value of 0.025 can be adopted as a safety side for evaluating the Design Flow Velocity

3.3.2 Velocity Concentration Ratio

Figure 3.5 shows a result of non-uniform flow calculation from 1548km to 1593km in Mekong River with the coefficient of roughness (n) value of 0.025. And Figure 3.6 shows the longitudinal distribution of the section mean velocity corresponding to Figure 3.5.
On the other hand, the mean velocity in the vicinity of the riverbank based on the flow velocity measurement executed by our study team are shown in Table 3.1 (1/4) to (4/4). Based on these data, section mean velocity (v_{avg}), riverside part mean velocity (v_{toe}), and velocity concentration ratio (v_{toe} / v_{avg}) of each pilot work site at discharge of the flow velocity measurement are shown as Table 3.2. In this study, v_{toe} is defined as the weighted mean velocity of whole field measurement area.

Table 3.1 (1/4) Mean Velocity by Measurement Results (Ban Dongphosi Site)

No. of Line	No. of Vertical	Distance (m)	Weighting Ratio	Measured Current Speed (m/s)			
				20% Depth	60% Depth	80% Depth	weighted average speed
Weighting Ratio				40%	30%	30%	
1	1	2	6.4%	0.0000		0.0000	0.0000
	2	5	7.3%	0.3994	0.4641	0.2659	0.3788
	3	10	13.6%	0.9035	0.7140	0.6579	0.7730
	4	20	18.2%	1.2137	0.9940	0.7958	1.0224
	5	30	18.2%	1.2137	1.1103	0.9380	1.1000
	6	40	18.2%	1.2611	1.1663	1.0543	1.1706
	7	50	18.2%	1.3688	1.1879	1.0543	1.2202
weighted average speed				1.0718	0.9417	0.8077	0.9535
2	1	2	6.4%	0.0000		0.0000	0.0000
	2	5	7.3%	0.1022	0.0806	0.0160	0.0699
	3	10	13.6%	0.8346	0.7398	0.6062	0.7376
	4	20	18.2%	1.0802	1.0414	0.9811	1.0388
	5	30	18.2%	1.1922	1.0457	0.9466	1.0746
	6	40	18.2%	1.1836	1.1491	0.9983	1.1176
	7	50	18.2%	1.3214	1.1836	1.0888	1.2103
weighted average speed				0.9898	0.9103	0.8138	0.9132
3	1	2	6.4%	0.0000		0.0000	0.0000
	2	5	7.3%	0.0720	0.0634	0.0160	0.0526
	3	10	13.6%	0.3262	0.4339	0.4555	0.3973
	4	20	18.2%	0.8174	0.6623	0.6493	0.7204
	5	30	18.2%	1.0543	0.9552	0.8561	0.9651
	6	40	18.2%	1.1793	1.0629	0.9380	1.0720
	7	50	18.2%	1.2568	1.1577	1.1189	1.1857
weighted average speed				0.8329	0.7616	0.7110	0.7750
4	1	2	6.4%	0.0000		0.0000	0.0000
	2	5	7.3%	0.0979	0.0548	0.0160	0.0604
	3	10	13.6%	0.2616	0.2960	0.3865	0.3094
	4	20	18.2%	0.5933	0.5072	0.4296	0.5184
	5	30	18.2%	0.8174	0.6192	0.5933	0.6907
	6	40	18.2%	1.0026	0.9552	0.8691	0.9483
	7	50	18.2%	1.1060	0.9681	0.9208	1.0091
weighted average speed				0.6827	0.5988	0.5653	0.6223
5	1	2	6.4%	0.2400		0.2056	0.2228
	2	5	7.3%	0.4253	0.2874	0.2099	0.3193
	3	10	13.6%	0.5675	0.5373	0.4038	0.5093
	4	20	18.2%	0.9078	0.8260	0.5890	0.7876
	5	30	18.2%	1.0242	0.9423	0.8174	0.9376
	6	40	18.2%	1.1232	0.9940	0.9294	1.0263
	7	50	18.2%	1.1232	1.0328	0.9208	1.0354
weighted average speed				0.8833	0.7842	0.6755	0.7912

Table 3.1 (2/4) Mean Velocity by Measurement Results (Ban Dongphosi Site)

No. of Line	No. of Vertical	Distance (m)	Weighting Ratio	Measured Current Speed (m/s) 20% Depth	60% Depth	80% Depth	weighted average speed
Weighting Ratio				40%	30%	30%	
6	1	2	6.4%	0.0000		0.0000	0.0000
	2	5	7.3%	0.1711	0.1323	0.0160	0.1129
	3	10	13.6%	0.7269	0.5847	0.5847	0.6416
	4	20	18.2%	0.9121	0.7527	0.6752	0.7932
	5	30	18.2%	1.0242	0.8561	0.7657	0.8962
	6	40	18.2%	1.1017	0.9164	0.8130	0.9595
	7	50	18.2%	1.0931	1.0026	1.0069	1.0401
weighted average speed				0.8627	0.7308	0.6738	0.7664
7	1	2	6.4%	0.0979		0.0160	0.0569
	2	5	7.3%	0.4210	0.4038	0.3951	0.4081
	3	10	13.6%	0.6709	0.6752	0.5632	0.6398
	4	20	18.2%	0.9423	0.8604	0.8044	0.8764
	5	30	18.2%	1.0974	0.9294	0.9337	0.9979
	6	40	18.2%	0.9466	0.9595	0.8820	0.9311
	7	50	18.2%	1.0974	1.0285	0.9251	1.0250
weighted average speed				0.8708	0.8083	0.7511	0.8162
8	1	2	6.4%	0.0000		0.0000	0.0000
	2	5	7.3%	0.0000	0.0000	0.0000	0.0000
	3	10	13.6%	0.3219	0.3477	0.3305	0.3322
	4	20	18.2%	0.7096	0.6666	0.6450	0.6773
	5	30	18.2%	0.9509	0.8992	0.7484	0.8747
	6	40	18.2%	1.0112	0.9121	0.7570	0.9052
	7	50	18.2%	0.8647	0.8260	0.7657	0.8234
weighted average speed				0.6869	0.6481	0.5753	0.6418
9	1	2	6.4%	0.0000		0.0000	0.0000
	2	5	7.3%	0.0160	0.0160	0.0160	0.0160
	3	10	13.6%	0.2357	0.3047	0.2487	0.2603
	4	20	18.2%	0.9078	0.7441	0.7312	0.8057
	5	30	18.2%	1.0026	0.8777	0.8001	0.9044
	6	40	18.2%	0.9294	0.8604	0.7484	0.8544
	7	50	18.2%	1.0069	0.9208	0.8174	0.9242
weighted average speed				0.7327	0.6614	0.5982	0.6710
Line No. 1,2,3,4,5 6,7,8,9 Averaged Speed	1	2	6.4%	0.0375		0.0246	0.0000
	2	5	7.3%	0.1894	0.1669	0.1057	0.1671
	3	10	13.6%	0.5387	0.5148	0.4708	0.6360
	4	20	18.2%	0.8983	0.7838	0.7001	0.9272
	5	30	18.2%	1.0419	0.9150	0.8221	1.0466
	6	40	18.2%	1.0821	0.9973	0.8877	1.1201
	7	50	18.2%	1.1376	1.0342	0.9576	1.2054
weighted average speed				0.8460	0.7606	0.6857	0.7723

Table 3.1 (3/4) Mean Velocity by Measurement Results (Wat Chom Cheng Site)

No. of Line	No. of Vertical	Distance (m)	Weighting Ratio	Measured Current Speed (m/s) 20% Depth	60% Depth	80% Depth	weighted average speed
Weighting Ratio				40%	30%	30%	
1	1	2	6.4%	0.0000		0.0000	0.0000
	2	5	7.3%	0.0000	0.0000	0.0000	0.0000
	3	10	13.6%	0.2443	0.3822	0.4210	0.3387
	4	20	18.2%	1.0026	0.8044	0.7398	0.8643
	5	30	18.2%	1.2094	0.9768	0.9466	1.0608
	6	40	18.2%	1.3473	1.1276	1.0026	1.1780
	7	50	18.2%	1.2353	1.1534	1.0715	1.1616
weighted average speed				0.9051	0.7907	0.7411	0.8216
2	1	2	6.4%	0.0000		0.0000	0.0000
	2	5	7.3%	0.1926	0.2271	0.2659	0.2250
	3	10	13.6%	0.6536	0.7527	0.5890	0.6640
	4	20	18.2%	0.8906	0.7527	0.6493	0.7769
	5	30	18.2%	1.0328	0.7829	0.9337	0.9281
	6	40	18.2%	1.0888	1.0974	0.9811	1.0590
	7	50	18.2%	1.2353	0.9466	0.9854	1.0737
weighted average speed				0.8754	0.7700	0.7450	0.8047
3	1	2	6.4%	0.0849		0.0000	0.0425
	2	5	7.3%	0.2314	0.2831	0.2271	0.2456
	3	10	13.6%	0.5761	0.6752	0.6019	0.6136
	4	20	18.2%	0.9897	0.8734	0.8604	0.9160
	5	30	18.2%	1.1620	0.9423	0.7829	0.9824
	6	40	18.2%	1.2482	1.0285	1.0026	1.1086
	7	50	18.2%	1.2008	1.1232	0.8647	1.0767
weighted average speed				0.9373	0.8340	0.7369	0.8462
Line No. 1,2,3, Averaged Speed	1	2	6.4%	0.0283		0.0000	0.0142
	2	5	7.3%	0.1414	0.1701	0.1643	0.1569
	3	10	13.6%	0.4914	0.6034	0.5373	0.5387
	4	20	18.2%	0.9610	0.8102	0.7499	0.8524
	5	30	18.2%	1.1347	0.9006	0.8877	0.9904
	6	40	18.2%	1.2281	1.0845	0.9954	1.1152
	7	50	18.2%	1.2238	1.0744	0.9739	1.1040
weighted average speed				0.9059	0.7982	0.7410	0.8241

Table 3.1 (4/4) Mean Velocity by Measurement Results (Sibounheuang Site)

No. of Line	No. of Vertical	Distance (m)	Weighting Ratio	Measured Current Speed (m/s)			
				20% Depth	60% Depth	80% Depth	weighted average speed
Weighting Ratio				40%	30%	30%	
1	1	2	6.4%	0.0000		0.0000	0.0000
	2	5	7.3%	0.4511	0.4425	0.4210	0.4395
	3	10	13.6%	0.5847	0.5072	0.4038	0.5072
	4	20	18.2%	0.7786	0.6924	0.6019	0.6997
	5	30	18.2%	0.8777	0.8217	0.7183	0.8130
	6	40	18.2%	1.0155	0.8949	0.8087	0.9173
	7	50	18.2%	0.9854	0.7915	0.6579	0.8290
weighted average speed				0.7775	0.6832	0.5924	0.6937
2	1	2	6.4%	0.2443		0.0000	0.1222
	2	5	7.3%	0.5933	0.5632	0.5072	0.5584
	3	10	13.6%	0.7096	0.5072	0.1280	0.4744
	4	20	18.2%	0.8303	0.7096	0.5201	0.7010
	5	30	18.2%	1.0328	0.7915	0.7613	0.8790
	6	40	18.2%	1.0112	0.8475	0.7743	0.8910
	7	50	18.2%	0.9380	0.8432	0.7484	0.8527
weighted average speed				0.8486	0.6905	0.5642	0.7158
3	1	2	6.4%	0.0000		0.0000	0.0000
	2	5	7.3%	0.2788	0.1194	0.0936	0.1754
	3	10	13.6%	0.4641	0.3822	0.2400	0.3723
	4	20	18.2%	0.7829	0.6536	0.5804	0.6834
	5	30	18.2%	0.9811	0.9251	0.8303	0.9190
	6	40	18.2%	0.9509	0.8863	0.7700	0.8772
	7	50	18.2%	0.9164	0.8044	0.8174	0.8531
weighted average speed				0.7438	0.6552	0.5846	0.6695
Line No. 1,2,3, Averaged Speed	1	2	6.4%	0.0814		0.0000	0.0407
	2	5	7.3%	0.4411	0.3750	0.3406	0.3911
	3	10	13.6%	0.5861	0.4655	0.2573	0.4513
	4	20	18.2%	0.7972	0.6852	0.5675	0.6947
	5	30	18.2%	0.9638	0.8461	0.7700	0.8703
	6	40	18.2%	0.9926	0.8762	0.7843	0.8952
	7	50	18.2%	0.9466	0.8130	0.7412	0.8449
weighted average speed				0.7900	0.6763	0.5804	0.6930

Table 3.2 Mean Velocity and Velocity Concentration Ratio

Pilot Work Site	Water Level (EL.m)[1)]	Discharge (observed) (m^3/s)	v_{avg}(calculated) (m/s)	v_{toe}(measured) (m/s)	v_{toe}/v_{avg}
a) Ban Dongphosi Site (1551.6km)	156.4	2,000	1.07	0.77	0.72
b) Wat Chom Cheng Site (1578.2km)	160.0	2,000	0.53	0.82	1.55
c) Sibounheuang Site (1589.0km)	161.4	2,000	0.77	0.69	0.90

1) Above M.S.L. Ko Lak Datum.

According to Thorne, Abt, and Maynold*), v_{avg} / v_{toe} of outer bank in a bend immediately downstream of straight channel in natural river is presumed by the equation as shown below,

$$v_{toe} / v_{avg} = 1.66 - 0.42 \log (r / B) \quad (3.1)$$

where r = radius of channel curvature, B = width of channel for the bend. This relation is adopted for r/B values equal to or greater than 2.
The value of the v_{toe} / v_{avg} at the same discharge is calculated by equation (3.1) by using r / B in each pilot work site as shown in the Table 3.3. (See Figure 3.7)

Table 3.3 Presumption of Velocity Concentration Ratio by Eq.(3.1)

Pilot Work Site	r (m)	B (m)	r / B	v_{toe} / v_{avg}
a) Ban Dongphosi Site (1551.6km)	4,000	560	7.2	1.30
b) Wat Chom Cheng Site (1578.2km)	3,000	670	4.5	1.39
c) Sibounheuang Site (1589.0km)	8,000	480	16.7	1.15

Considering above results, it is understood to be able to apply equation (3.1) to some extent, but the value of v_{toe} / v_{avg} in each site should be regarded as follows as a safety side.

a) Ban Dongphosi Site : $v_{toe} / v_{avg} = 1.3$
b) Wat Chom Cheng Site : $v_{toe} / v_{avg} = 1.4$
c) Sibounheuang Site : $v_{toe} / v_{avg} = 1.2$

3.3.3 Evaluation of Design Flow Velocity

Design flow velocity v_0 of the bank protection work is set as a riverside part mean velocity at the discharge of the river channel brimmer.
The section mean velocity (v_{avg}) at the discharge of the river channel brimmer is calculated by the non-uniform flow calculation. The riverside part mean velocity (v_{toe}) is calculated from v_{avg} by using v_{toe} / v_{avg}.
Laotian side bank elevation in each pilot work site, discharge and section mean velocity for channel brimmer, v_{toe} / v_{avg}, and v_{toe} (= v_0) are as shown in Table 3.4.

Table 3.4 Evaluation of Design Flow Velocity

Pilot Work Site	Bank Elevation (EL.m) [1)]	Discharge (m^3/s)	v_{avg} (m/s)	v_{toe} / v_{avg}	v_{toe} (= v_0) (m/s)
a) Ban Dongphosi Site (1551.6km)	168.1	22,900	2.58	1.3	3.4
b) Wat Chom Cheng Site (1578.2km)	169.9	19,900	1.85	1.39	2.6
c) Sibounheuang Site (1589.0km)	170.1	18,100	2.30	1.15	2.6

1) Above M.S.L. Ko Lak Datum.

*) Colin R.Thorne, S.R.Abt, S.T.Maynold : Prediction of Near-Bank Velocity and Scour Depth in Meander Bends for Design of Riprap Revetments, River, Coastal And Shoreline Protection, Edited By Colin R.Thorne…et.al., John Wiley & Sons Ltd, 1995

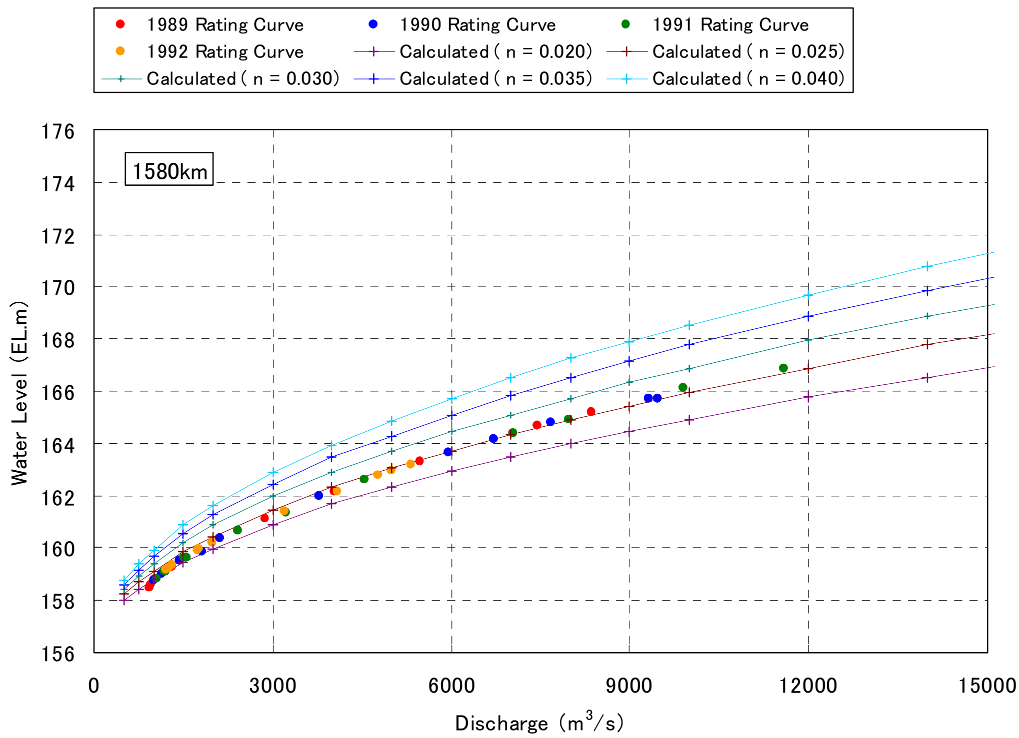

Figure 3.3 Measured And Calculated Rating curve At Vientiane KM4 (Water level is indicated as above M.S.L. Ko Lak Datum.)

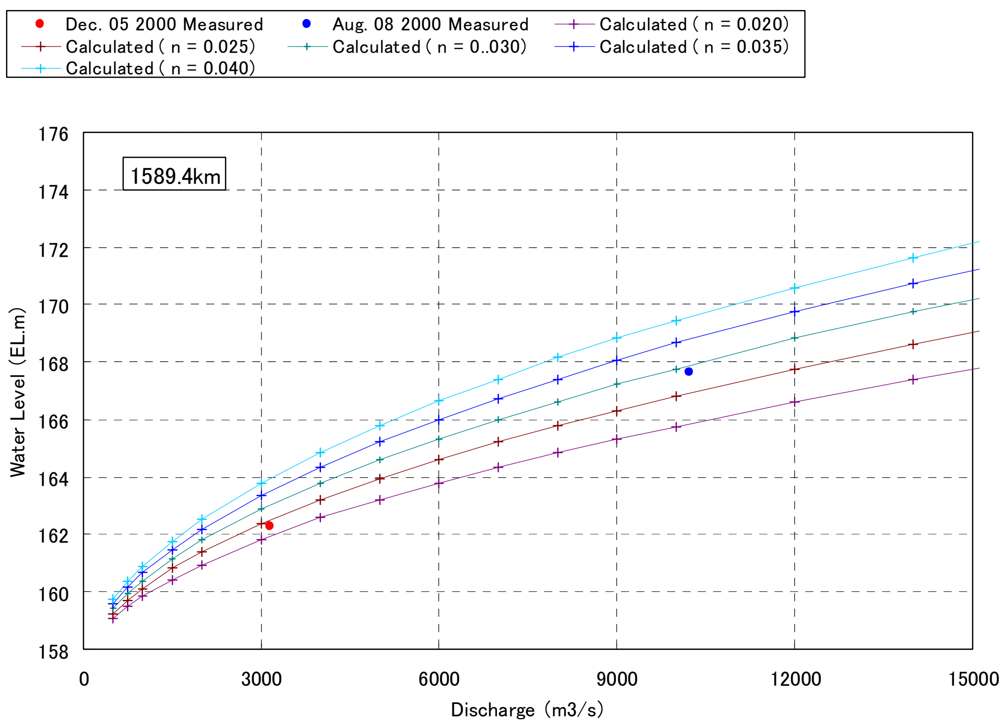

Figure 3.4 Measured and Calculated Rating Curve in the Sibounheuang Site Neighborhood (Water level is indicated as above M.S.L. Ko Lak Datum.)

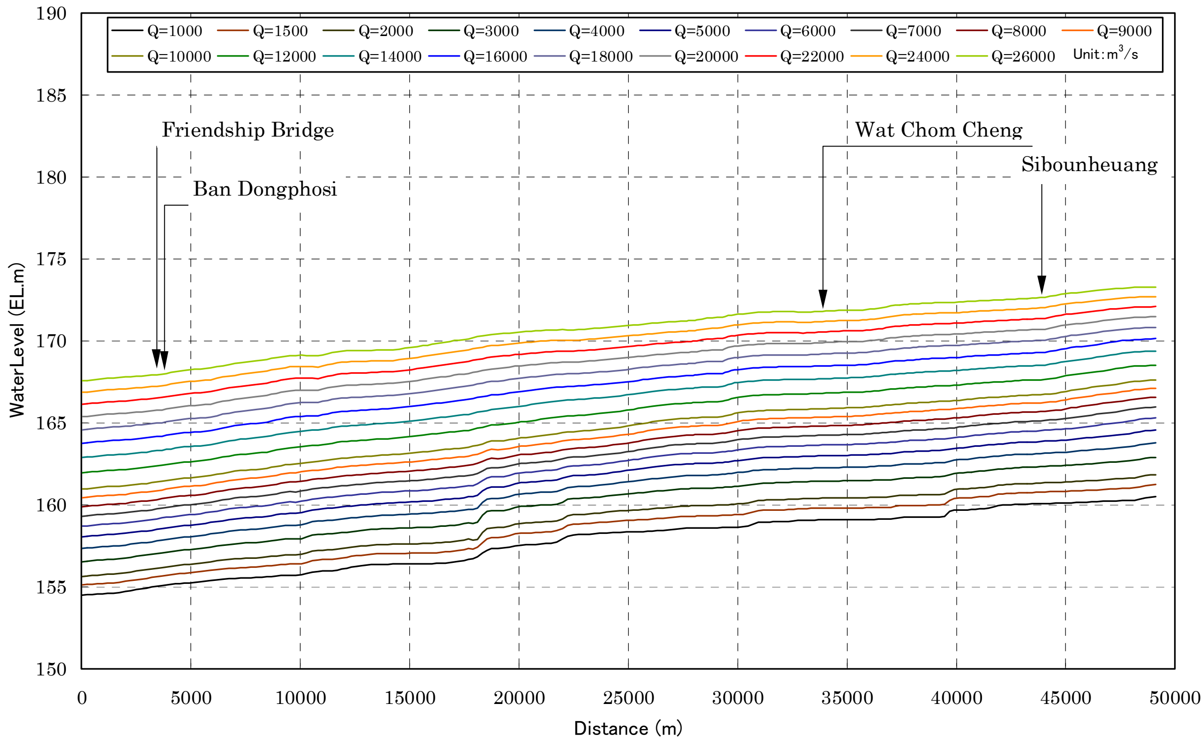

Figure 3.5 Result of Non-Uniform Flow Calculation from 1548km to 1593km

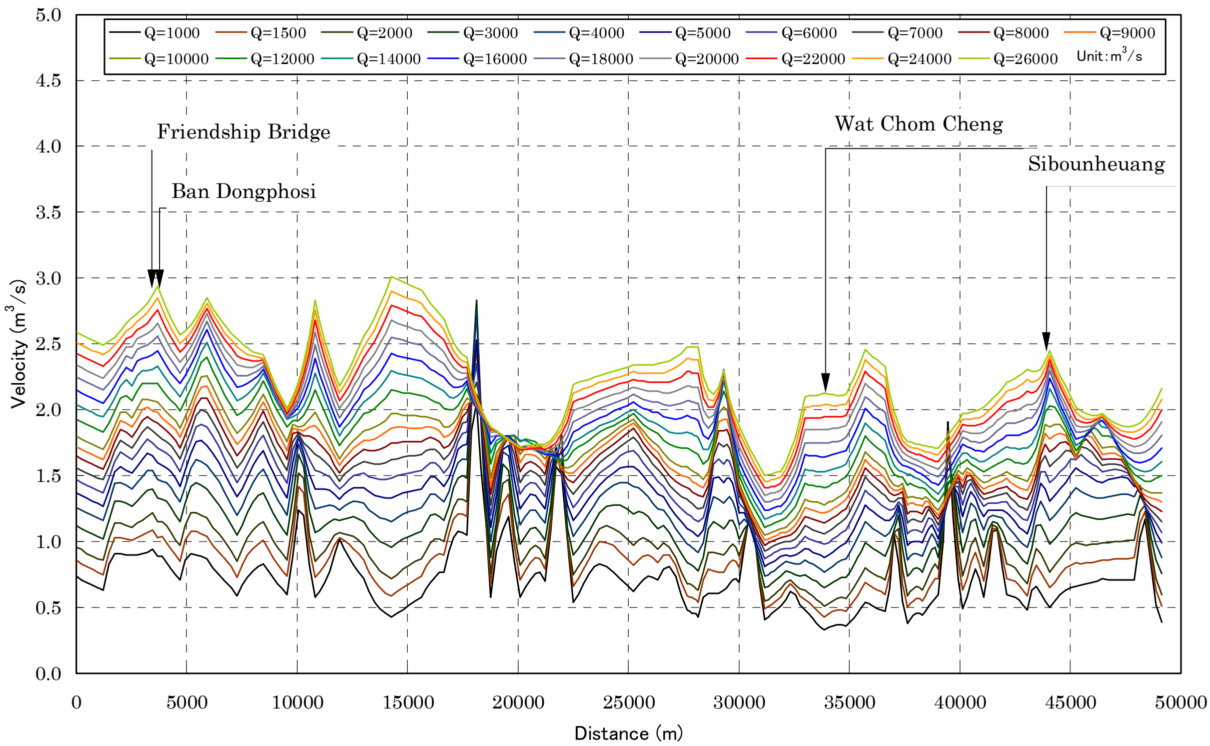

Figure 3.6 Longitudinal Distribution of the Section Mean Velocity (Calculated)

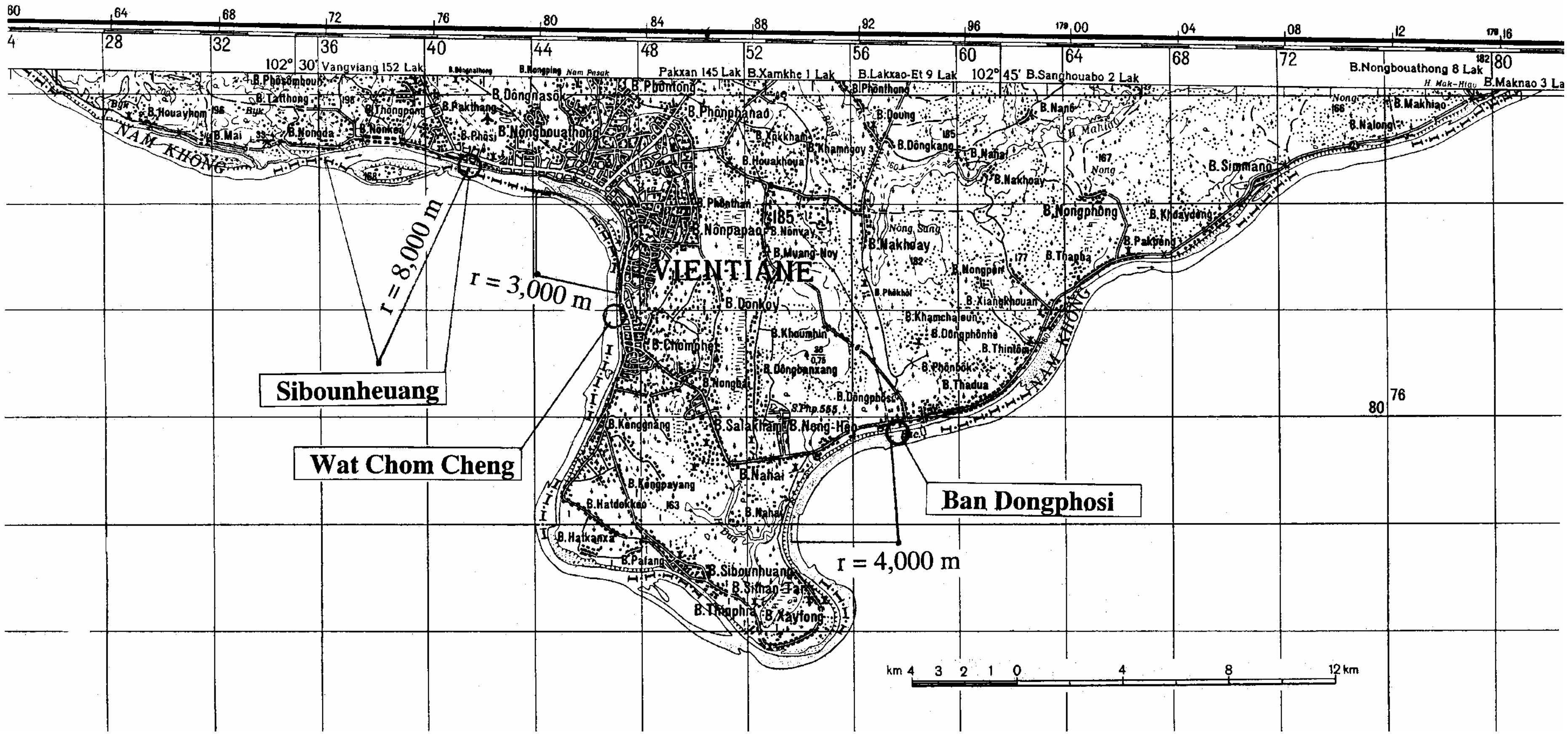

Figure 3.7 Evaluation of Radius of Channel Curvature (r)

3.4 Water Level

3.4.1 Low Water Level at Each Site

Lowe water level is set as water level, under which annual lowest water level occurs with in a return period of 5 years.
At KM4 port, the water level with return period of 5 years is estimated as approximately EL.+158.30m above Ko Lak Datum, based on the series of annual lowest water level observed at Laxy Port in 1960 – 2001.
Low water level at each site is estimated using the difference of lowest water level since 1960. The result is as shown in Table 3.5.

Table 3.5 Low Water Level at Each Site

Pilot Work Site	L.L.W.L. (EL.m)[1)]	L.W.L. with 5 years Return Period (EL.m)[1)]	L.W.L. with 5 years Return Period (EL.m)[2)]
c) Ban Dongphosi Site (1551.6km)	154.5	155.1	155.0
d) Wat Chom Cheng Site (1578.2km)	157.6	158.2	158.1
d) Sibounheuang Site (1589.0km)	158.4	159.0	158.9
e) Laxy Port (KM4)	157.75	158.3	158.2

1) Above M.S.L. Ko Lak Datum, 2) Above Hon Dau Datum

3.4.2 Water Level Variation at KM4

Water level variation at KM4 for a period of 1992-2001 is processed to obtain average monthly water level including average mean, average maximum and average minimum value. The results are as shown in Figure 3.8.
In October, the average mean water level is estimated as approximately EL.164.0m. The average maximum and average minimum are EL.166.0m and EL.162.7m, respectively.

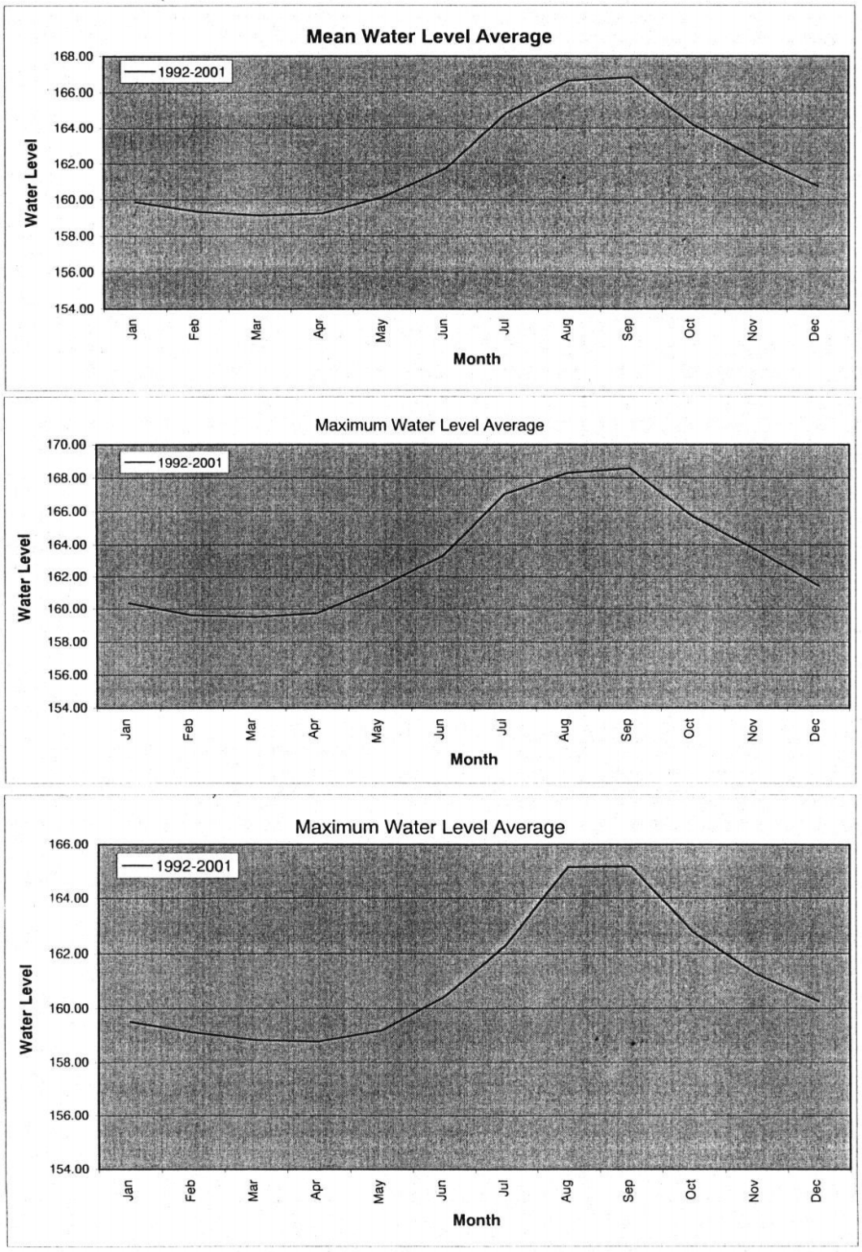

Figure 3.8 Water Level Variation at KM4