No.

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
THE GOVERNMENT OF LAO P.D.R.

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

FINAL REPORT
VOLUME 2
MAIN REPORT

DECEMBER 2004

NIKKEN Consultants, Inc.
NEWJEC Inc.

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PREFACE

In response to a request from the Government of Lao People's Democratic Republic (hereinafter, Lao P.D.R) the Government of Japan decided to conduct the Study on Mekong Riverbank Protection around Vientiane Municipality in the Lao P.D.R. and entrusted to study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Yasuhiko KATO of NIKKEN Consultants, Ins. (consisting of NIKKEN Consultants, Inc. and NEWJEC Inc.) to Lao P.D.R. five times between December 2001 and December 2004.

In addition, JICA set up an Advisory Committee headed by Mr. Ichiro MORIKAWA, former Director of Foundation of Riverfront Improvement and Restoration between December 2001 and March 2003, and headed by Mr. Masamitsu MIZUNO, Director of Foundation of Riverfront Improvement and Restoration between April 2003 and December 2004. The Committee examined the Study from technical point of view.

The team held discussion with the officials concerned of the Government of Lao P.D.R and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of this project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Lao P.D.R. for their close cooperation extended to the Study.

December 2004

Etsuo KITAHARA

Vice-President
Japan International Cooperation Agency

December 2004

Mr. Etsuo KITAHARA
Vice-President
Japan International Cooperation Agency (JICA)
Tokyo, Japan

LETTER OF TRANSMITTAL

It is with great pleasure that we submit to you the Final Report of the Study on Mekong Riverbank Protection around Vientiane Municipality in the Lao People's Democratic Republic.

The study has been made of formulate a Riverbank Protection Master Plan on the Mekong River around Vientiane City through the execution of the Riverbank Protection Pilot Works introducing Japanese traditional river works. This Report includes all the study results and consists of Summary, Main Report, Manual, Supporting Report and Data Book.

We hope that this Report will be helpful for the riverbank protection in critical areas along the Mekong River around Vientiane City.

We wish to express our deep appreciation and gratitude to the personnel concerned of your Agency, JICA Laos Office, the Embassy of Japan in Lao P.D.R., Ministry of Communication, Transport, Post and Construction, Department of Communication, Transport, Post and Construction of Vientiane City and other authorities concerned of the Lao P.D.R. for the countries and cooperation extended us during our Study.

Very truly yours,

Yasuhiko KATO

Team Leader
for the Study on Mekong Riverbank
Protection around Vientiane Municipality
in the Lao People's Democratic Republic

COMPOSITION OF FINAL REPORT

VOLUME 1 EXECUTIVE SUMMARY

VOLUME 2 MAIN REPORT

VOLUME 3 MANUAL FOR RIVERBANK PROTECTION

SECTOR A PLANNING & DESIGN
SECTOR B CONSTRUCTION

VOLUME 4 SUPPORTING REPORT

SECTOR A PRESENT CONDITION IN THE STUDY AREA
SECTOR B PREPARATORY STUDY FOR PILOT WORKS
SECTOR C FIELD SURVEY FOR PILOT WORKS
SECTOR D EXECUTION OF PILOT WORKS
SECTOR E TEST OF SIMPLE VEGETATION RIVERBANK PROTECTION
SECTOR F MONITORING OF PILOT WORKS
SECTOR G MONITORING SURVEY FOR PILOT WORKS
SECTOR H RIVERBANK PROTECTION MASTER PLAN
SECTOR I ENVIRONMENTAL CONSIDERATION
SECTOR J TRANSFER OF TECHNOLOGY

VOLUME 5 DATA BOOK

The cost estimate in this study is based on the price level at the beginning of February 2004 and the applied foreign currency exchange rates are as stated below:

EXCHANGE RATE

US Dollar (US$) 1.00 = Lao Kip (Kip) 10,420
Japanese Yen (¥) 100 = Lao Kip (Kip) 9,750
Middle rate as of February 1, 2004

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

FINAL REPORT
VOLUME 2
-MAIN REPORT-

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ABBREVIATIONS

(1) Organization

Lao P.D.R.	Lao People's Democratic Republic
GOL	Government of Lao P.D.R.
GOJ	Government of Japan
JICA	Japan International Cooperation Agency
MCTPC	Ministry of Communication, Transport, Post and Construction
DOR	Departments of Roads, MCTPC
DCTPC	Department of Communication, Transport, Post and Construction
VUDAA	Vientiane Urbane Development and Administration Authority
LNMC	Lao National Mekong Committee
ADB	Asian Development Bank
IUCN	International Union for the Conservation of Nature and Natural Resource
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNDP	United Nations Development Programme
UNCHS	United Nations Centre for Human Settlements
FITA	Flanders International Technical Agency
RTSB	Rancang Timur Sdn. Bhd., Malaysia

(2) Place Name, Geographical Name or Project Name

VUISP	Vientiane Urban Infrastructure and Services Project
NBCA	National Biodiversity Conservation Area

ABBREVIATIONS OF MEASUREMENT

Length

mm	=	millimeter
cm	=	centimeter
m	=	meter
km	=	kilometer
ft	=	foot
yd	=	yard

Area

cm^2	=	square centimeter
m^2	=	square meter
ha	=	hectare
km^2	=	square kilometer

Volume

10^6	=	million
cm^3	=	cubic centimeter
l	=	litre
kl	=	kilolitre
m^3	=	cubic meter
gal	=	gallon

Weight

Gwh	=	Gigawatthour
mg	=	milligramk
g	=	gram
kg	=	kilogram
ton	=	metric ton
lb.	=	pound

Time

s	=	second
min	=	minute
h	=	hour
d	=	day
y	=	year

Electrical Measurement

V	=	Volt
A	=	Ampere
hz	=	Hertz (cycle)
Ghz	=	Gigahertz
W	=	Watt
kW	=	kilowatt
MW	=	Megawatt
GW	=	Gigawatt
pr	=	pair

Other Measures

%	=	percent
PS	=	horsepower
o	=	degree
‘	=	minute
“	=	second
10^3	=	thousand
10^9	=	billion

Derived Measures

m^3/s	=	cubic meter per second
cusec	=	cubic feet per second
mgd	=	million gallon per day
kWh	=	Kilowatthour
Mwh	=	Megawatthour
Wh/y	=	Killowatthour per year
kVA	=	kilovolt ampere
BTU	=	British Thermal Unit
psi	=	pound per square inch
Icd	=	litre per capita per day
Kb/s	=	Kilobot/second
Mb/s	=	Megabit/second

Currency

US$	=	US Dollar
Kip	=	Laotian Kip

1 INTRODUCTION

1.1 General

This Final Report is prepared in accordance with Scope of Work for "The Study on Mekong Riverbank Protection around Vientiane Municipality in the Lao P.D.R." (hereinafter referred to as "the Study") which was agreed upon between Department of Roads, Ministry of Communication, Transport, Post and Construction (hereinafter referred to as "MCTPC"), the Government of Lao People's Democratic Republic (hereinafter referred to as "GOL") and Japan International Cooperation Agency (hereinafter referred to as "JICA") of the Government of Japan (hereinafter referred to as "GOJ") on July 19, 2001.

1.2 Background of Study

Vientiane City has been suffering from damages due to riverbank erosion of the Mekong River. The damages extend to main roads, urban lands, houses, oil stockpiling bases, factories and electric cables. In order to cope with this erosion situation, GOL executed the bank protection works mainly with gabions. The gabion works, however, are costly because of imported iron wire mesh basket.

JICA Expert dispatched to GOL from 1997 implemented, in a tentative manner, low-cost groin works in Bokeo Province with local stone materials and labor forces. In addition, Infrastructure Development Institute, Japan (hereinafter referred to as "IDI") implemented bank protection test works at Sibounheuang in Vientiane City from 1999 to 2001 introducing Soda mattress works, a traditional river works in Japan. These works proved the favorable results.

With these backgrounds, GOJ decided to conduct the Study. JICA, who is responsible for the implementation of the technical cooperation of GOJ, has entrusted the Study work since 2001 with the cooperation of MCTPC, who acts as a coordinating body in relation with relevant organizations concerned for the smooth implementation of the Study.

1.3 Objectives of Study

1.3.1 Objectives of the Study

The Study aims to conduct the following for the Mekong River around Vientiane City:

1. To study practical bank protection works with lower cost adaptable to the Mekong River and sustainable in Lao P.D.R., introducing river works developed in Japan.
2. To transfer technology related with the above works to the counterpart personnel through the execution of Pilot Works.
3. To formulate a master plan for riverbank protection of the Mekong River around Vientiane City based on the monitoring results of the Pilot Works.

1.3.2 Goal of the Study

Goal of the Study is to make root of practical and sustainable riverbank protection measures which fit well with the characteristics of the Mekong River in Lao P.D.R. Conceptual relationship between the Study and the goal is shown in Figure 1.1. Addressing to the goal, the bank protection measures should satisfy the following requirements:

1. Measures fitting with river nature: The bank erosion is an inherent nature of the river. Bank protection measures to conserve lands and properties should be planned, designed and implemented appropriately fitting with the nature of the Mekong River.
2. Measures sustainable in Lao P.D.R.: It may be difficult to expect continuous input from the outside considering the type of works. GOL and local communities should sustain the measures from the technical, economic, social and environmental aspects. Use of local materials and participation of local people are, therefore, needed.
3. Measures with lower cost: Financial conditions of GOL are severely constrained, while the sites requiring measures are many. Development and introduction of low cost measures are expected.
4. Measures to create favorable river environment: River is a living and amenity space for the residents near the river. Especially in the urban area, it provides an invaluable natural environment. Nowadays importance of this function of the river is globally understood. Therefore, conservation and creation of favorable river environment should be taken into consideration in planning the bank protection measures.

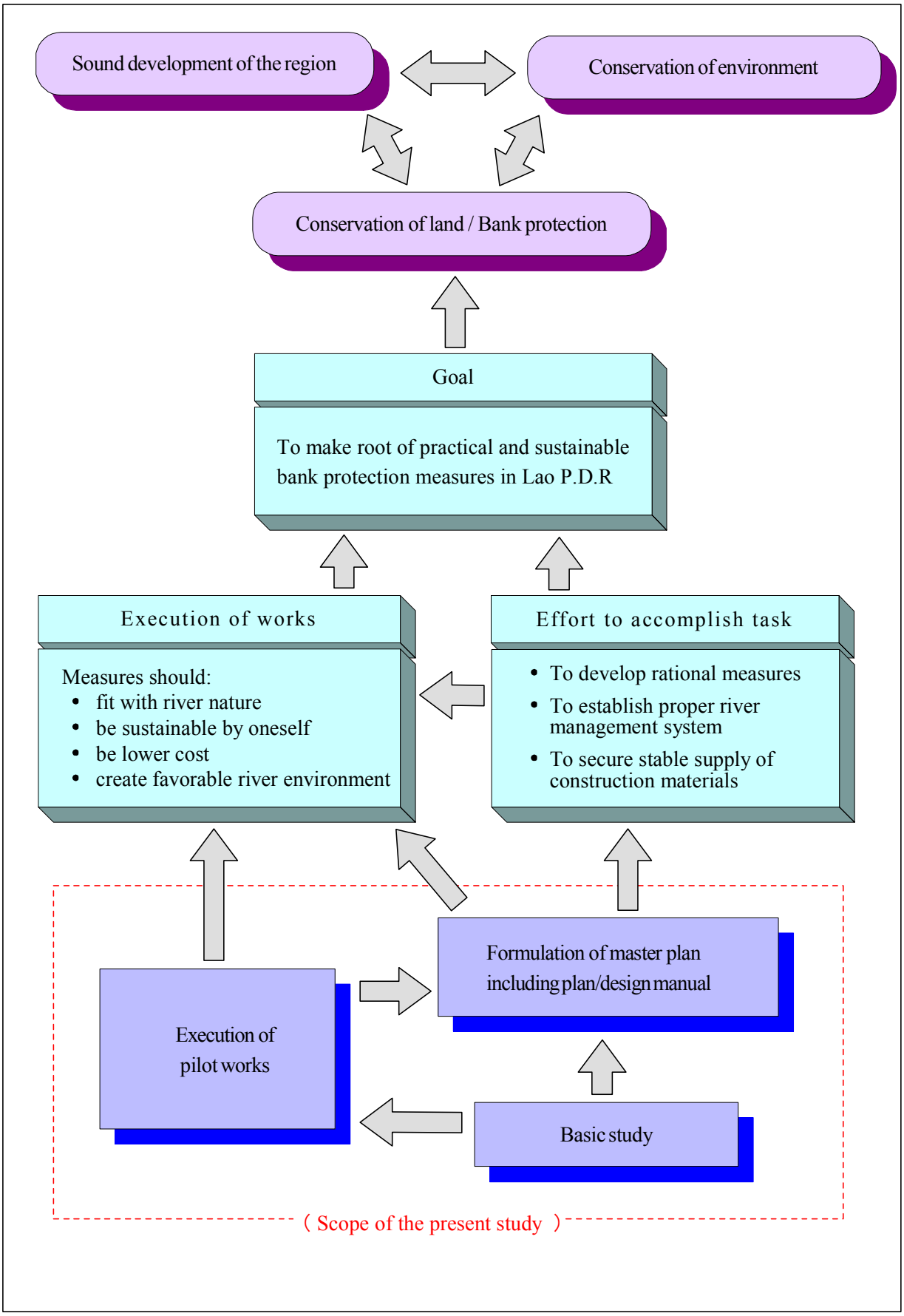


Figure 1.1 Scope of Present Study and Goal

1.4 Study Area

The Study Area is the Mekong riverbank around Vientiane Capital City in Lao P.D.R. with a stretch of approximately 60 km. The Study Area is shown in Figure 1.2.

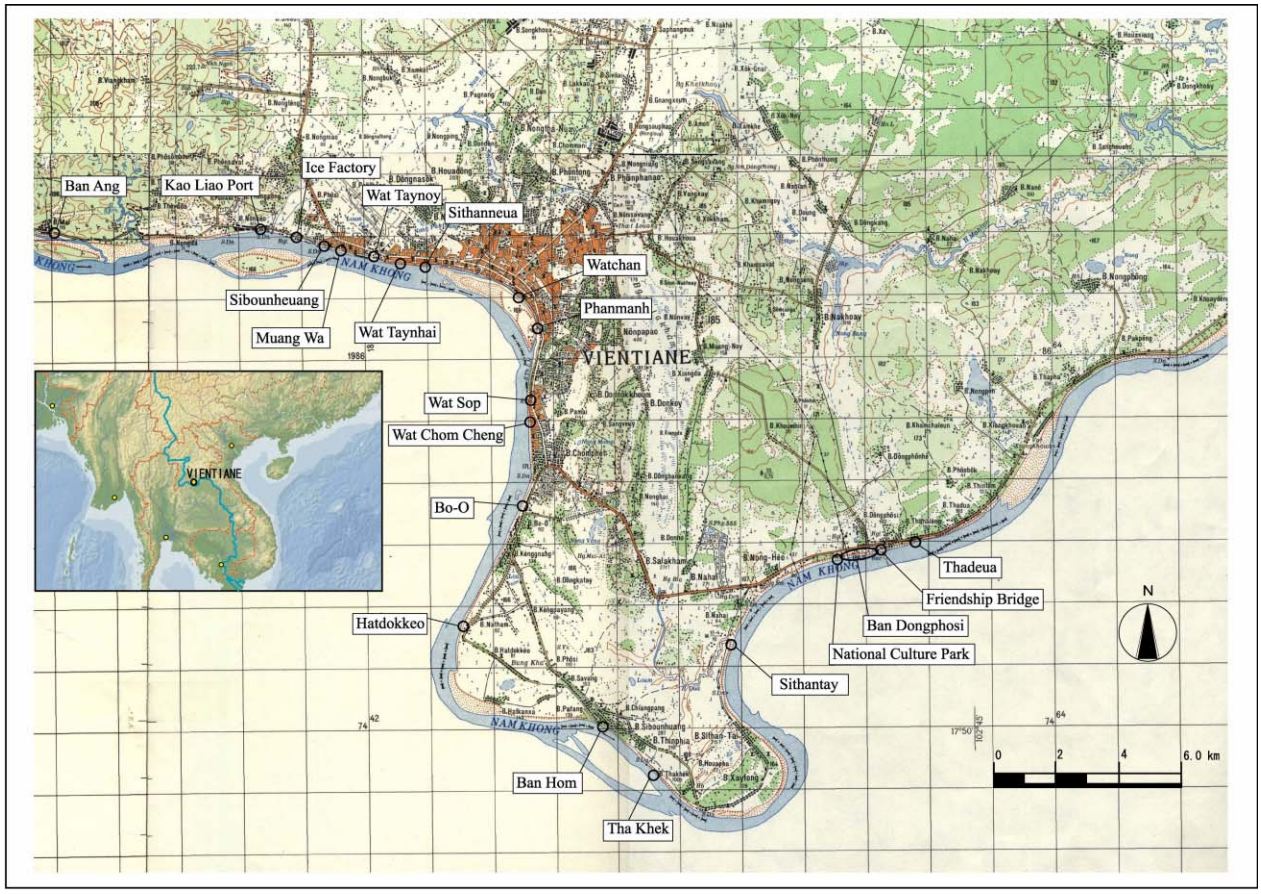


Figure 1.2 Location of Study Area

1.5 Study Schedule

Overall schedule of the Study from December 2001 to December 2004 and the major contents conducted is as shown in Figure 1.3.

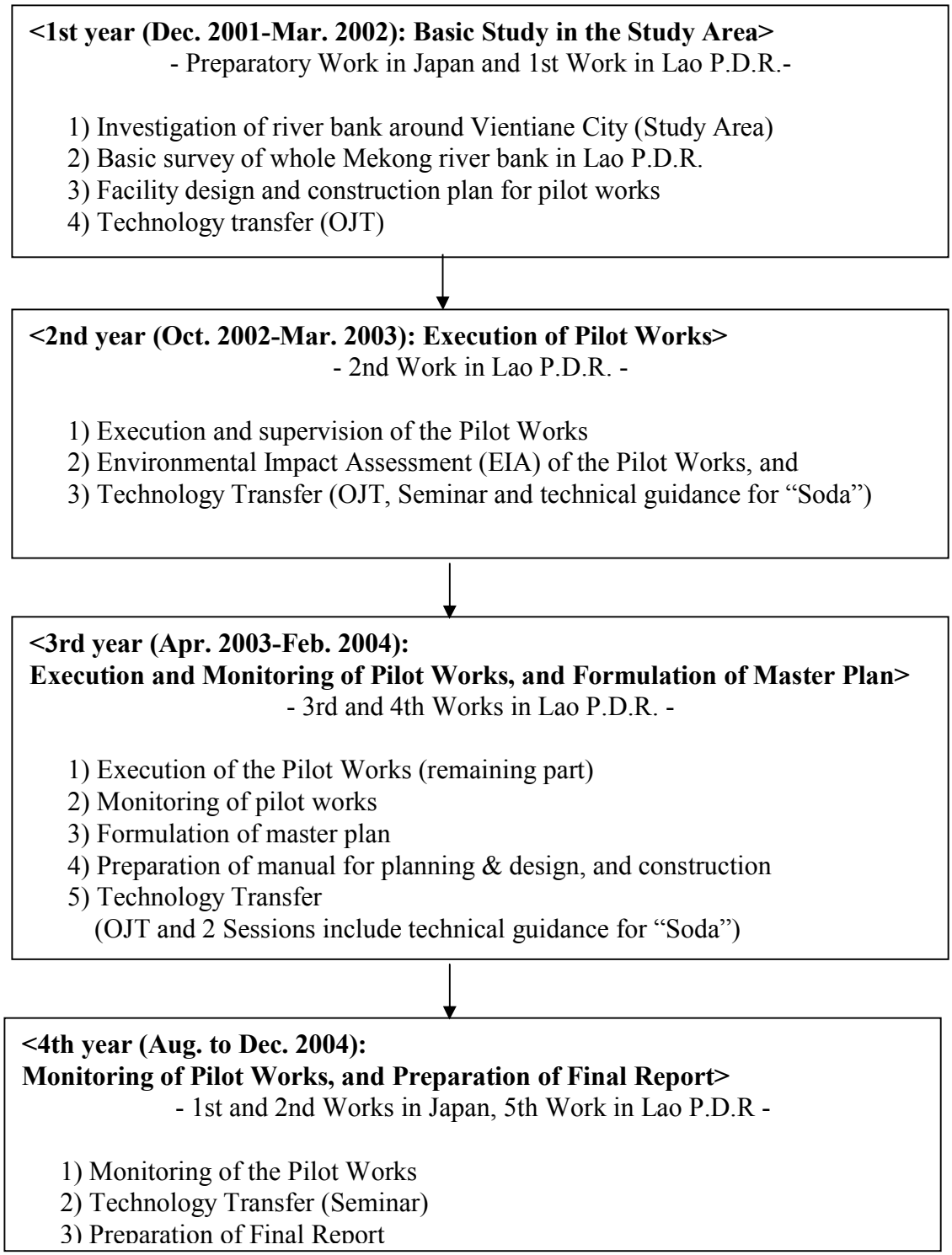


Figure 1.3 Overall Schedule of the Study

1.6 Study Organization

JICA Study Team is composed of the following thirteen (13) members as follows:

Name	Task
Mr. Yasuhiko KATO	Team Leader/ Bank Protection Plan
Dr. Rokuro KOBAYASHI	Co-Team Leader/ Structure Design
Mr. Noboru JITSUHIRO	River Morphology-Geology
Dr. Hideki OTSUKI	Hydrology
Mr. Tsutomu KAMEYAMA	Construction Plan/ Cost Estimate
Mr. Shozo SHIMODA	Topo-Survey
Mr. Shingo OHASHI	Soda Technique Guidance
Mr. Kanji WATANABE	Environment
Ms. Ikuko KAWABATA	General Vegetation
Mr. Takeo NAKAGAWA	Fascine Material
Mr. Megumi KAWAHARA	Geotechnical Investigation
Mr. Tetsuya TERAUCHI	Study Coordination (Dec. 2001-Mar.2003)
Mr. Hiroki WATANABE	Study Coordination (Dec. 2003-Dec.2004)

JICA Advisory Committee consists of members as follows:

Name	Task
Mr. Ichiro MORIKAWA	Chairman of the Committee (Dec. 2001-Mar. 2003)
Mr. Masamitsu MIZUNO	Chairman of the Committee (Apr. 2003-Dec. 2004)
Mr. Shuei UKISU	Committee Member

The government of Lao P.D.R (GOL) has organized a counterpart team consisting of the following members:

Name	Organization
Mr. Viengsavanh PHASAVATH	DOR, MCTPC
Mr. Bounthieng VENVONGSOTH	DOR, MCTPC
Mr. Khamfong SOUVANNAVONG	DOR, MCTPC
Mr. Litta KHATTIYA	DOR, MCTPC
Ms. Anousa BOUASISAVATH	DOR, MCTPC
Mr. Somchith SITHIPHONG	DCTPC
Mr. Khammouath SOMCHITVONGSA	DCTPC

The Steering Committee for the Study was established with the following GOL members:

Name	Organization
Mr. Sommad PHOLSENA	MCTPC
Mr. Sourasay PHOUMAVONG	MRC
Mr. Nousone MUNVISIETH	VUUDA
Mr. Somchith SITHIPHONG	DCTPC
Mr. Somnuk CHANTHASIETH	MOAF

2 BASIC STUDY

This Chapter 2 compiles the main result of the basic study composed of the following items:

1) Present condition in the Study Area
2) Preparatory study for the Pilot Works, and
3) Field survey for the Pilot Work design.

The details of this chapter are compiled in Volume 4, Supporting Report as follows:

1) Sector A -Present Condition in the Study Area
2) Sector B -Preparatory Study for Pilot Works
3) Sector C -Field Survey for Pilot Works

2.1 Present Condition in the Study Area

2.1.1 Hydro-meteorological Condition

Hydro-meteorological condition in the Vientiane City, the Study Area is summarized as follows:

- Annual rainfall: around 1,640 mm in average
  - Rainy season: May to September (1,390 mm in average; 85 % of annual rainfall)
  - Dry season: October to April (250 mm in average; 15 % of annual rainfall)
- Average temperature: 26.3 ^{O}C
- Annual maximum water level and discharge (1960-2001):
  - 6.67 m - 12.71 m (10.68 m in average)
  - 7,500 m3/s- 22,900 m3/s (16,000 m3/s in average)
- Annual minimum water level and discharge (1960-2001):
  - -0.28 m - 0.93 m (0.43 m in average)
  - 598 m3/s-1,220 m3/s (1,000 m3/s in average)

2.1.2 Riverbank Condition around Vientiane City (the Study Area)

(1) Characteristics of the Mekong River in the Study Area

Characteristics of the Mekong River in the Study Area are as follows:

- Average riverbed slope: 1/8,100
- Average maximum channel depth: 14.87 m
- Average river width: 856 m (including island), 773 m (excluding islands)
- Riverbed materials: Average of the 60 % grain sizes (d60) are 0.44 mm with the specific gravity at 2.61.

(2) Riverbank Condition

Riverbank condition in the Study Area is summarized as follows:

- The riverbanks severely eroded in the Study Area forms vertical cliffs mostly as shown in Figure 2.1.
- The riverbanks in the Study Area seem younger and sediment movements are mere active comparing with those in other reaches, since the Study area is located just downstream of the abrupt change of river slope.
- Riverbank generally consists of sandy gravel layer covered with clayey soil (6 m to 8 m deep) on the top. These bank materials are not consolidated and easily be eroded.
- Gabion works are commonly used for bank protection. The existing works are effective to protect the riverbank from erosion, though some works are damaged due to poor foot protection and/or washing away of soil behind the gabion.

Sithantai

Ban Hom

Bo O

Sibounheuang

Figure 2.1 Eroded Cliffy Riverbanks in the Study Area
- Condition in December 2001-

(3) Riverbank Alignments and Islands

Condition of the riverbank alignments and the islands in the Study Area is as follows:

- Historical change of riverbanks and islands: During past 30 years, changes in riverbanks are not much as a whole, and the islands remained almost at the same location. The riverbank movements are relatively large in the stretch from KM-1574 to KM-1562.
- Course of main flow: The bank erosions in the Study Area are mainly caused by the

attacking river flows and the reaches of flow attacks are historically fixed.
- Average intervals of meandering cycle: about 8.5 km (about 10 times of river width)

(4) Sediment Flow Conditions

Sediment Flow Condition in the Study Area is as follows:

- Dune bed under the frequent flood flow conditions and flat bed under the bankfull flow condition.
- Sediment transport: Suspension not fully developed

(5) Causes of Bank Erosion

Main causes of the bank erosion of the Mekong River are as follows:

- Erosion due to scouring at foot of riverbed (The vertical riverbank cliffs would be formed in this manner and most of the eroded river banks in the Study Area are of this type.)
- Erosion due to excess pore pressure during lowering period of river water level
- Erosion due to slope failure

2.1.3 Riverbank Condition of Whole Mekong River in Lao P.D.R.

Field reconnaissance of whole Mekong River in Lao P.D.R. was made during the period from December 2001 to February 2002 to compare the condition with that in the Study Area, Vientiane City and to obtain helpful information applicable to the Study Area.

(1) Southern Part of Whole Mekong River
(Bolikhamxai, Khammouan, Savannakhet and Champasak Provinces)

- Vertical cliffs of riverbanks commonly seen in the Study Area are seldom found.
- Near Wat Phu remain (World Heritage) in Champasak province (refer to Figure 2.2): A part of the remnants of exterior wall of Wat Phu located at the eroded riverbank is now under constant threat of collapse. Revetment works covering whole river bank is not recommendable in consideration of the conservation and archaeological prospecting of remains. Groin works might be effective to stabilize the bank by accelerating the sedimentation and vegetation at the foot of eroded bank.



Figure 2.2 Mekong Riverbank near Wat Phu Remain
- Condition in December 2001-

(2) Northern Part of Whole Mekong River (Luang Phabang and Bokeo Provinces)

- In the urban area of Luang Phabang, riverbanks are rather stable and keep some gentle slope and the extent and damage of erosion is relatively small as shown in Figure 2.3.
- In Bokeo province, the riverbanks, most notably existing groin site at Ban Tonpheung form vertical cliffs at many places as shown in Figure 2.4 as can seen in the Study Area.



Figure 2.3 Mekong Riverbank along Luang Phabang City
- Condition in January 2002-

Figure 2.4 Mekong Riverbank in Bokeo Province
- Condition in January 2002-

2.1.4 Existing Bank Protection Works

(1) Around Vientiane City (the Study Area)

Present condition of the existing bank protection works in the Study Area is summarized as follows and shown in Figure 2.5.

- Bank protection works along the Mekong River around Vientiane City have been implemented since early 1990s.
- Most of the protection works were done by using gabion. As for these works, at many locations, silt deposits with partly covered by vegetation are found. Some of wire nets have been corroded to become thin and partly damaged in a long period after construction.
- At Wat Sibounheuang, a new method using Soda mattress has been tested.
- At Hatdokkeo, gabion at the toe of the slope is damaged and stones in the net-cage are lost, resulting a steep slope of toe without being protected. Existing sand excavation works near the site might have influenced the riverbed degradation in front of the work.

Thadeua

National Culture Park

Hatdokkeo

Wat Sop

Muang Wa

Sibounheuang

Figure 2.5 Existing Riverbank Protection Works in the Study Area
-Condition in December 2001-

(2) Whole Mekong River in Lao P.D.R. (Southern part from Vientiane)

Field reconnaissance was made in December 2001 to compare the condition with that in the Study Area, Vientiane City and to obtain helpful information applicable to the Study Area.

- At Pakkadan in Bolikhamxai province, four riprap groins have been constructed and two new groins are under construction along the national road No.13 (refer to Figure 2.6). Further extension of groin is planned. With somewhat low elevation of the groin crown, the sedimentation between the groins is realized under the groin level. Slope of the embankment between the groins is suffered from partly collapse due to high velocity in the flood season. Slightly higher groins and/or the combination of slope protection works as riprap works between groins are supposed to be effective.
- At the confluence with Nam Xan river in Bolikhamxai province, the riverbank was severely damaged. Repair of embankment founded by groins are under construction. The slopes between groins are considered still vulnerable against erosion. Riprap protection works are recommended for the slope protection in addition to the groins.

Figure 2.6 Riprap Low Groins at Pakkadan
- Condition in February 2002-

- At Thakhek, gabion works protect a water intake facility with concrete piles supported by "Soda mattress" and wooden pile works (refer to Figure 2.7).
-

Figure 2.7 Soda Mattress Installed Site at Thakhek
- Condition in December 2001-

(3) Whole Mekong River in Lao P.D.R. (Northern part from Vientiane)

Field reconnaissance was made in January 2002 to compare the condition with that in the Study Area, Vientiane City and to obtain helpful information applicable to the Study Area.

- Around Luang Phabang city, riverbank slope of the Mekong is rather stable except the drainage treatment on the slopes.
- In Luang Phabang city, along the Nam Khan river near the confluence with the Mekong, riverbank is protected by gabion box. Some amount of silt deposit is found on the gabions.
- Along Ban Tonephueng in Bokeo province, riprap groin works being executed by GOL with the technical assistance of JICA Expert to MCTPC since 1998 as shown in Figure 2.8. Amount of sedimentation is found between groins, resulting to protect the riverbank slopes. MCTPC constructed 14 groins by 2003 and will continue further extension until 2008, every 2 groins a year.

Figure 2.8 On-going Riprap Groin Works in Bokeo Province
- Condition in December 2001-

2.1.5 Proposed Plans and Projects in the Study Area

(1) Bank Protection Plans and Projects

The following plans and projects relating to river bank protection are reviewed for the basis of the formulation of the Master Plan:

Proposed future bank protection plans and projects around Vientiane City (the Study Area) by national budget and other donors are summarized below and in Table 2.1.

1) Projects by National Budget

GOL has been implementing bank protection works gradually by using very limited national budget. Proposed projects after 2004 are as follows so far:

1. Sibounheuang (L=410 m): to be implemented after 2005 (survey was started from 2004)
2. Ban Hom/Tha Khek: 60 m to be constructed in 2004, construction to be continued

2) Lao-Flanders River Works Project

The outline of the project is as follows:

1. On-going capacity development project at Bo O riverbank site (2002-2004) of MCTPC financially assisted by Flanders International Technical Agency (FITA), the Government of Belgium.
2. Survey for L=200 m is completed and the design of bank protection works using gabion has not been completed; the draft drawing is available.
3. Construction work will be executed by national budget; GOL is requesting FITA for the financial aid, though.

3) Projects by Other Donors

No specific future plans and projects by other donors exist so far except present technical cooperation by JICA and FITA. However, if donor's financial assistance is available in the future, it will help GOL to accelerate the implementation of the Master Plan.

Table 2.1 Proposed Bank Protection Plans and Projects in the Study Area

Site Name	Existing Bank Protection Works	Surveys and Studies for Bank Protection										Remarks
		Project Type			Length of construction (m)	Work Type	Topo-Survey	Hydrological Survey	Facility Design	Budget (mil Kip)	Source of Funds	Year of Construction	
		New	Exten -sion	Rehabili -tation									
Sithantai	No	Yes	-	-	3,500	Under consideration	Yes (3,500 m in 2000 and 2001)		No	No	National budget	Unknown	
Thakhek - Ban Hom	No	-	Yes	-	2,000	Foot protection work by riprap & backfill	No (to be implemented 2 km in 2005		No	600 (for 60 m in 2004)	National budget	from 2004	
Hatdokkeo	Yes (EU & National budget)	-	-	Yes	100	Foot protection work by riprap	Yes (520 m in 2000)		No	No	National budget	Unknown	
Bo O	Yes	-	Yes	-	200	Backfill, riprap & reno mattress	Yes (200 m in 2002-2003)			No	National budget or GOB aid	from 2005?	*GOL implemented bank protection work in 2002 and 2003. *Government of Belgium (GOB) has been conducting a capacity building project for bank protection here (2002-2004). *GOL is requesting of GOB for the financial aid for the construction.
Chinaimo (near Bo O)	No	Yes	-	-	-	No	No			No	National budget	Unknown	
Wat Chan /Don Chan Island Development	Yes (Land reclamation)	Yes	Yes	-	Unknown	Land reclamation for urban development	Yes			Unknown	Malaysian Private company (RTSB)	from 2003	*Modern Home Co. Ltd. implemented L=840 m. Original plan (L=6,000 m) is greatly scale downed and suspended owing to shortage of funds. *Malaysian private company (RTSB) is now developing Don Chan island (including bank protection).
Sibounheuang	Yes (IDI & JICA, Japan)	-	Yes	-	approx. 410	Soda mattress & Cobble stone with willow branch work	No <to be implemented in 2005.>			50 (for survey & design in 2004)	National budget	from 2005	GOL will implement bank protection work applying JICA's pilot work method.
Kao Liao (between ice factory and Kaoliao port)	Yes (National budget)	-	Yes	Yes	300	Under consideration	No			No	National budget	Unknown	

(2) Related Plans and Projects

No flood control plan of the Mekong River in Lao P.D.R. is available so far, which will affect riverbank protection. Urban development plans/projects in Vientiane City are closely related to riverbank protection. Outline of the several plans/projects are described here.

1) Urban Development Project by Reclamation at Watchan

- Modern Home Co. Ltd., Laotian private developer, completed reclamation work (L=840 m) in 2002 The layout of 1st phase project is shown in Figure 2.9.
- Modern Home Co. Ltd. abandoned original Don Chan Island development owing to financial difficulty.

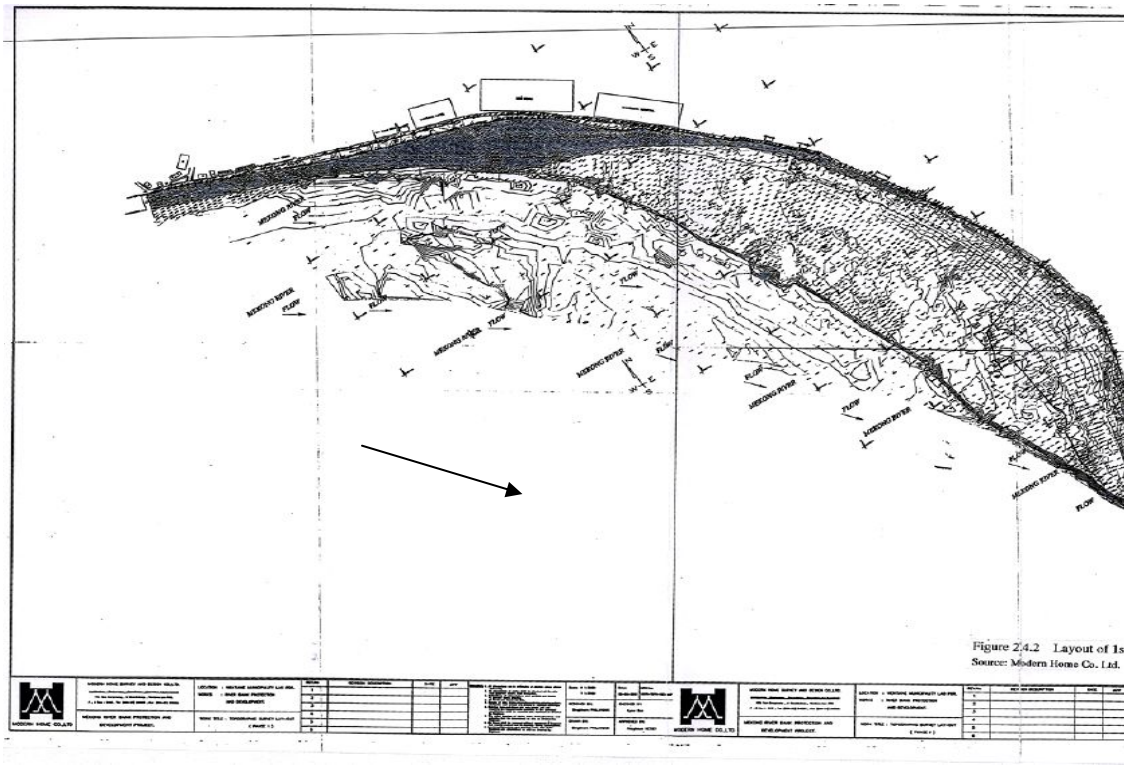


Figure 2.9 Layout of Land Reclamation by Modern Home's Project

(Source: Modern Home Co. Ltd.)

2) On-going Don Chan Island Development

- Don Chan Island (100ha) will be fully developed and urbanized by Rancang Timur Sdn. Bhd. (RTSB), Malaysia as shown in Figure 2.10.
- Bank protection of the island will be executed by RTSB.
- Sand mining in the Mekong River for reclamation might cause some impact to riverbank.
  - On-going MRC study "Environmental Risk Assessment between Non Kai and Vientiane" including sediment transport can be utilized in near future.

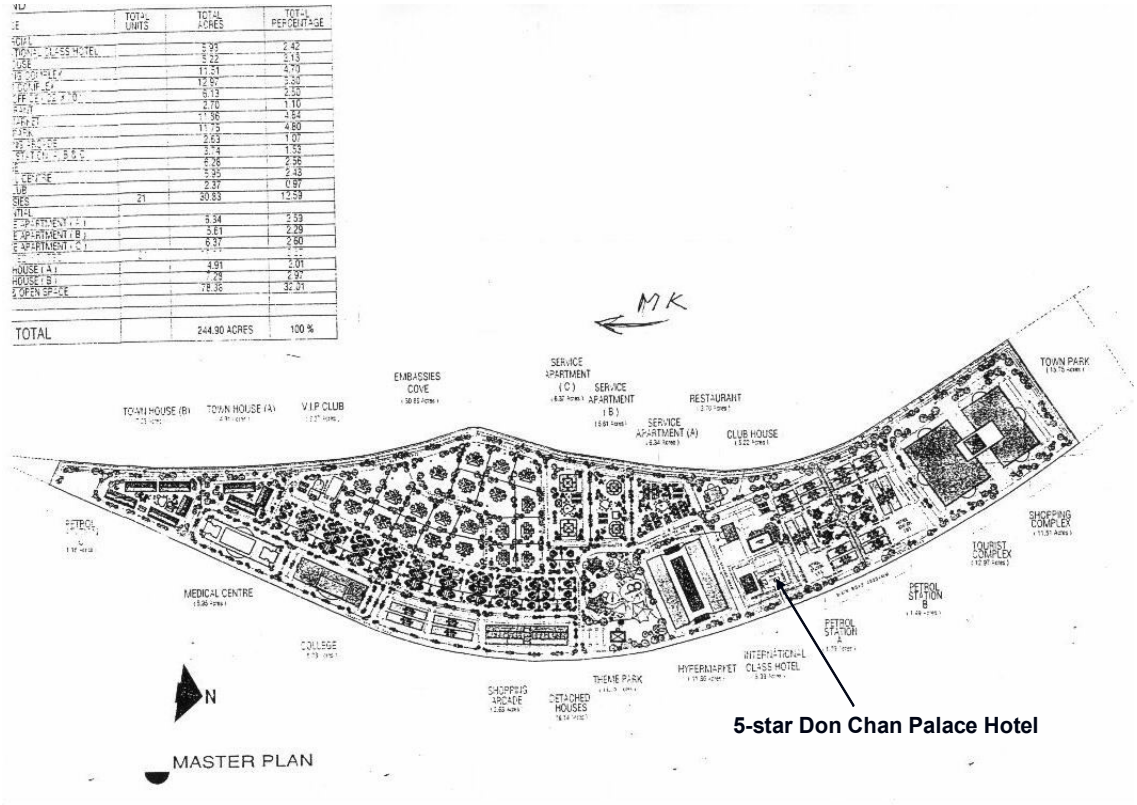


Figure 2.10 General Layout of Don Chan Island Development

(Source: MCTPC)

3) Vientiane Urban Development Master Plan

The draft of revised Vientiane Urban Development Master Plan (URI-MCTPC, 2003) proposed the land use principles of riverine area as shown in Figure 2.11. The plan has a close relation with the non-structural measures of JICA Master Plan.

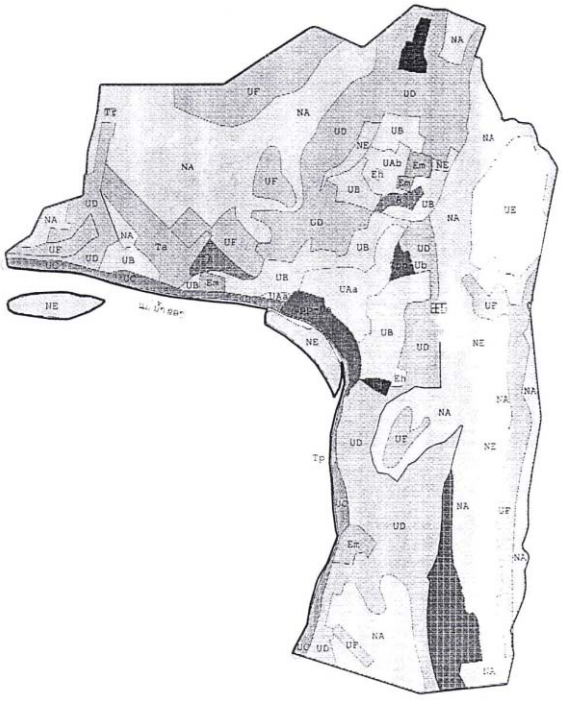


Figure 2.11 Future Land Use Zoning in Vientiane City

4) Vientiane urban infrastructure and service project (VUISP)
- formulated by VUDAA/ADB in 2001
- Riverbank protection project around Sibounheuang (L=1.06 km) was excluded from the original component.

5) Committee for prevention of impacts on river banks and ecology system
- established by Prime Minister's Decree in April 2003 as national level activities including Vientiane
- Setting up of organization and implementation schedule of the committee: now under consideration

2.1.6 Riverine Vegetation in the Study Area

Condition of the vegetation along the Mekong River in the Study Area is as follows:

(1) Vegetation on Natural Riverbank

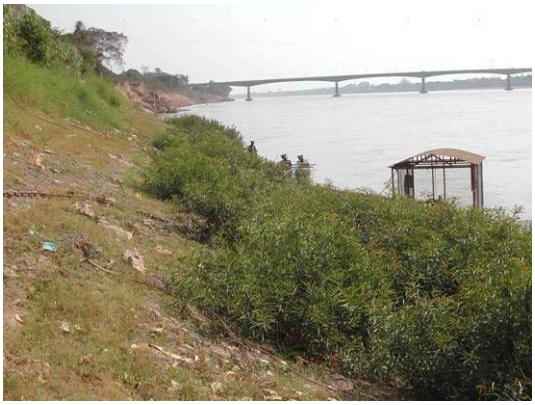
- Little vegetation grows on the bank forming vertical cliff.
- Vegetation grows on the stable bank with gentle slope.

(2) Vegetation on Existing Bank Protection Works

- Growing plants change with the situation of sedimentation.
- The kinds of distributed plant differ in the upper, middle and lower layers of bank.
- Growth of plant is not active for one year after the completion of work

(3) Willow in the Mekong River

- Distribution of willow:
  - Many communities of the willow are found at existing bank protection works after 5 years or more from the completion as shown in Figure 2.12.
  - Few willows are found on natural riverbanks
  - Massive communities are found at the sandbar in front of Buddha Park.
- Characteristics of willow:
  - The kind of soil has little influence on the growth of willow.
  - Moisture has strong influence on the growth of willow
  - Community of willow can hold the soil of riverbank



National Culture Park

Mekong Restaurant near KM4

Figure 2.12 Community of Willow on Existing Bank Protection Works

2.1.7 Basic Environmental Condition in the Study Area

Basic environmental condition in the Study Area was investigated with the assistance of a local consultant under the supervision by the Study Team

(1) Natural Environment

- Protected Area: Phou Phanang and Phou Khao Khoay National Biodiversity Conservation Areas (NBCA) (refer to Figure 2.13)
- Fauna and flora: Natural vegetation areas remain well in and around above NBCAs. There is no natural vegetation along the Mekong riverbank.

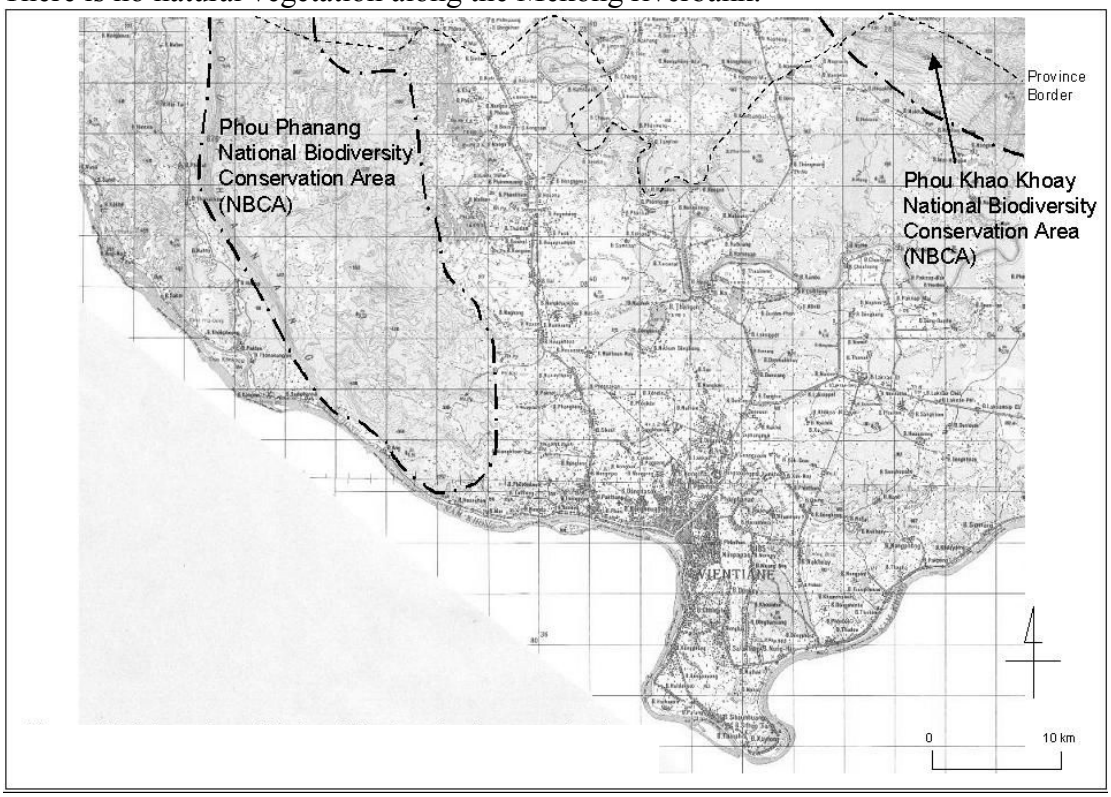


Figure 2.13 NBCAs around the Study Area

(2) Social Environment

- Forestry law in Lao P.D.R.:
  - Forest are categorized 1) protected forests, 2) forest reserves, 3) production forests, 4) rehabilitation forests and 5) degraded forests
  - Wood and other forest products can be exploited only from production forests.
- Riverine land use: 1) field, 2) field with trees, 3) residential area, 4) residential area with trees and 5) commercial area

2.1.8 Socioeconomic and Financial Conditions

(1) Socioeconomic Condition of the Study Area

Socioeconomic conditions of Lao PDR and Vientiane City are summarized in Table 2.2.

Table 2.2 Socioeconomic Conditions of Lao PDR and Vientiane City

Item	Unit	Lao PDR	Vientiane City
1. Population in 2002	1,000	5,526	639 (2003)
Average annual growth rate (1995-2002)	%	2.73	2.51
Population density	person/km2	23	163
2. Gross Domestic Product			
In US$ (2002)	M US$	1,815	582 (2002/03)
Average growth rate (1992-2002, actual)	%	6.3	9 (2002/03)
3. GDP per capita	US$/person	329	887
4. Inflation rate in 2003	%	15.5	
5. Foreign exchange rate on Feb.1, 2004	Kip/US$	10,420	

(2) Socioeconomic Development Plans

GOL emphasizes to eliminate the country's poverty by 2020. Economic growth target of National Socioeconomic Development Plans: around 7% p.a. Long-tem, Medium-term and 5 years development plan is as shown in Table 2.3, 2.4 and 2.5, respectively.

Table 2.3 Targets of Development Plan for 2020

Item	Target
1. Annual GDP growth	around 7% p.a.
2.Total investment	25 - 30% of GDP
Public investment	12 - 14% of GDP
Private investment	13 - 16% of GDP
National saving	at least 15% of GDP (in 2020)
3.Population	8.3 million (in 2020)
Average growth rate	2.2% p.a.
4.GDP per capita	1,200 - 1,500 US dollars
5.Literacy rate (15years and over)	90%
6.Life expectancy	70 years

Table 2.4 Targets of 2010 Development Plan

Item	Target
1. Annual GDP growth	7% p.a.
2.Population	6.7 million (in 2010)
Population growth rate	2.4% p.a.
3.GDP per capita	700 - 750 US dollars
4.Literacy rate (15 years and over in 2010)	84%
5.Life expectancy	67 years

Table 2.5 Targets of 5 Years Socio-economic Development Plan V (2001 - 2005)

Item	Target
1. Annual GDP growth	7 - 7.5% p.a.
2.Annual growth and share by industry	
(1) Agriculture and forestry	4 - 5% p.a./47% of GDP
(2) Industry	10 - 11% p.a./26% of GDP
(3) Services	8 - 9% p.a./27% of GDP
3.Annual inflation rate	**Less than 10%**
4.Exchange rates	Stabilize
5.Annual budget revenue	To increase up to 18% of GDP (during 2004-2005)
Budget deficit	To decrease to 5% of GDP
6.Trade balance	To decrease deficit to 6% of GDP
7.Public investment	12 - 14% of GDP
National saving	12% of GDP (in 2005)
8.Population	5.9 million (in 2005)
9.GDP per capita	500 - 550 US dollars

(3) Financial Conditions

1) National Revenue and Expenditure

Average annual growth rate of both the revenue and expenditure is approximately 8% on an actual basis, which is higher than that of economic growth rate of the country (6.3%) during the same period as shown in Table 2.6.

Table 2.6 Government Finance

Unit: Billion Kip

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total revenue	131	156	209	241	284	335	823	1,403	2,485	2,317	2,858
Total expenditure	175	189	266	310	375	463	1,146	1,709	3,016	3,055	3,749
of which current expenditure	93	130	148	166	173	200	299	541	1,095	1,296	1,419
of which capital expenditure	82	58	118	144	202	264	847	1,167	1,921	1,759	2,329
Fiscal balance	-45	-33	-57	-69	-91	-128	-323	-305	-531	-738	-890
Ratio (revenue/expenditure)	75%	83%	78%	78%	76%	72%	72%	82%	82%	76%	76%

Source: The National Poverty Eradication Programme, September 2003

The fiscal deficit has been covered by foreign and domestic financing including ODA loans and grants. Around three-quarters of the capital expenditure come from ODA on average as shown in Table 2.7.

Table 2.7 Source of Capital Expenditure Budget

Unit: Million US$

	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02
Capital Expenditure	210	216	240	276	303	235	245	192
from ODA	166	161	181	204	233	171	147	93
from Government	44	55	59	72	70	64	98	99
Ratio of ODA	79%	75%	75%	74%	77%	73%	60%	48%

Source: Foreign Aid Report 2001 - 2002, June 2003

As shown in Table 2.8, debt-service ratio (DSR), a kind of country risk assessment factors, has been increasing gradually and has reached 11.7% in 2002, which is still manageable level of indebtedness. The National Poverty Eradication Programme clearly states that the Government firmly commits to gradually lessen the country's high dependency on ODA.

Table 2.8 Foreign Debt Service

Million US$

	1996	1997	1998	1999	2000	2001	2002
Total value of export	317.2	312.7	336.8	301.5	330.3	309.8	321
Total debt service	15.5	19	21.3	28.4	28.8	34.9	37.4
Debt-service ratio	4.9%	6.1%	6.3%	9.4%	8.7%	11.3%	11.7%

Source: The National Poverty Eradication Programme, September 2003

2) Expenditure for Riverbank Protection

The significant extension in FY 2002/03 is achieved by the Pilot Works implemented in this JICA study as shown in Figure 2.14.

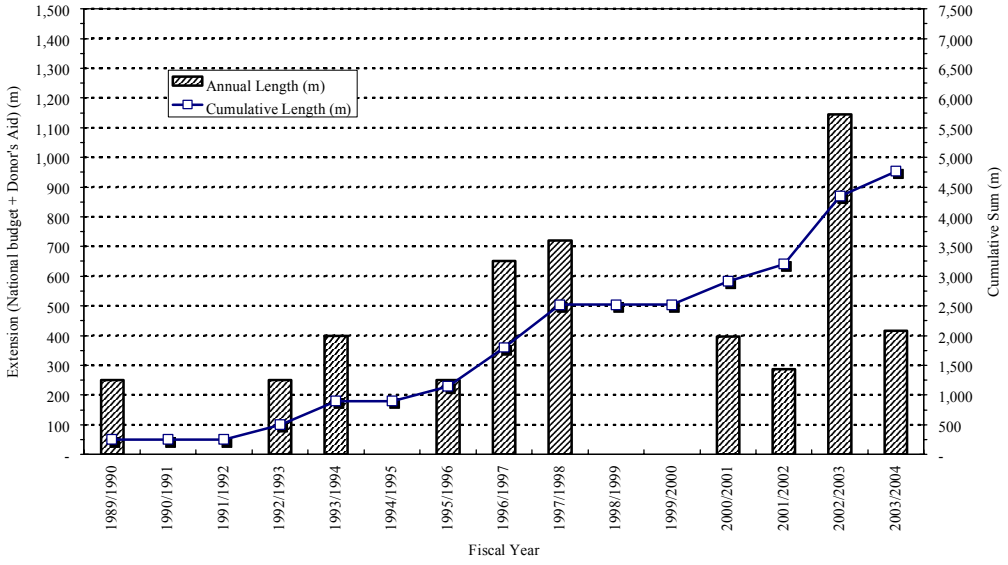


Figure 2.14 Extension of Existing Bank Protection Works in Vientiane

Riverbank protection works of the Mekong River is basically implemented by the budget of MCTPC except some urgent cases. MCTPC is the largest ministry in public investment, which accounts for approximately 40% of the total public investment. Table 2.9 shows changes of annual budget of MCTPC.

Table 2.9 Budget of MCTPC

Unit: Billion Kip

	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04
MCTPC Total	65.3	130.4	391.3	670.9	705.1	420.3	519.5	760.6
of which Road Construction (A)	65.0	75.0	168.4	575.0	473.1	410.2	345.2	615.5
Ratio of Road Construction	99%	57%	43%	86%	67%	98%	66%	81%
of which River works (B)	0.5	0.5	0.3	1.6	1.4	2.6	15.6	4.1
Ratio (B)/(A)	0.7%	0.6%	0.1%	0.3%	0.3%	0.6%	4.5%	0.7%

Source: MCTPC

The annual investment has remained less than 1% of the budget for road construction except FY2002/03, when JICA Pilot Works were implemented as illustrated in Figure 2.15.

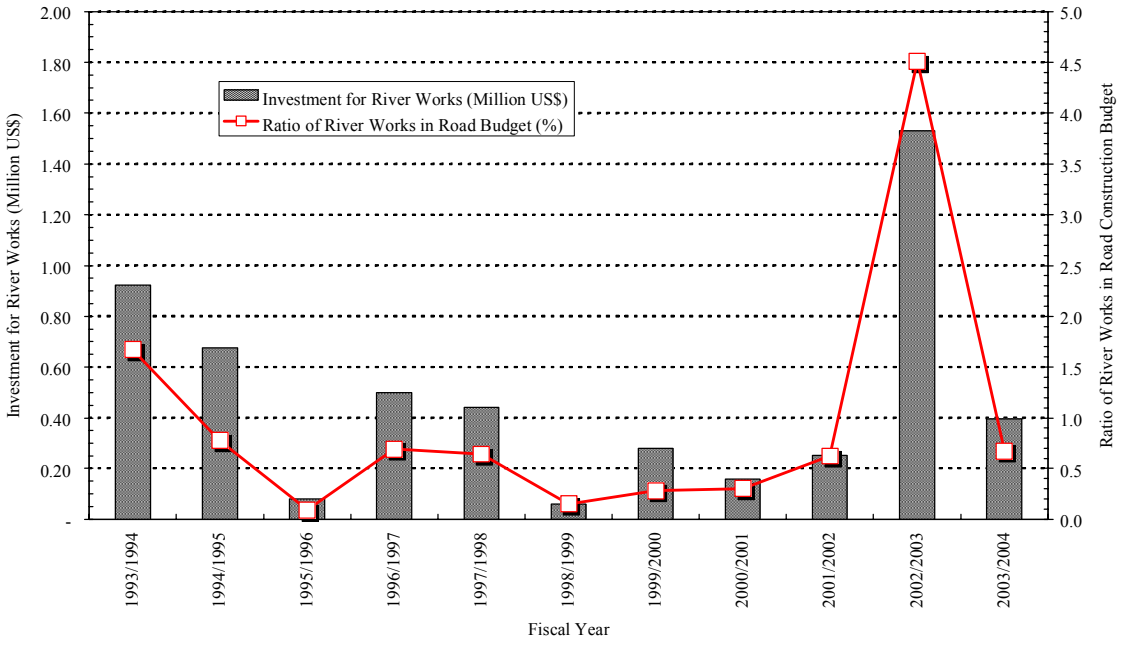


Figure 2.15 Investment for River Works in Lao PDR

As shown in Figure 2.16, since FY1997/98, riverbank protection works has been gradually undertaken by national budget. However, on the contrary, external assistance for riverbank protection has decreased significantly except Japanese test construction.

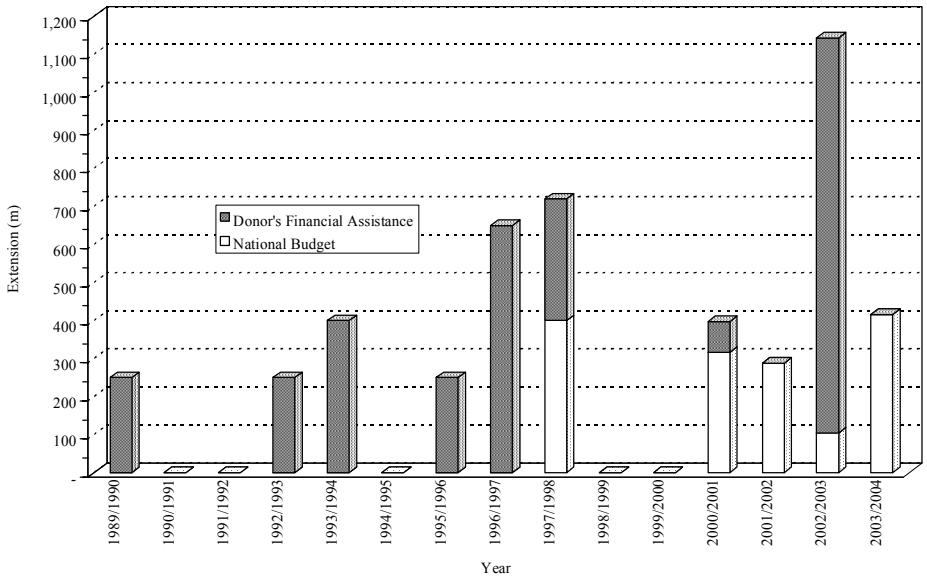


Figure 2.16 Riverbank Protection Works around Vientiane City by Source of Finance

2.2 Preparatory Study for Pilot Works

2.2.1 Selection of Sites for Pilot Works

The following three (3) sites are selected for the bank protection Pilot Works (the Pilot Works):

1. Ban Dongphosi site (L=643 m)
2. Wat Chom Cheng site (L=240 m)
3. Sibounheuang Site (L=156 m)

The location is as shown in Figure 2.17.

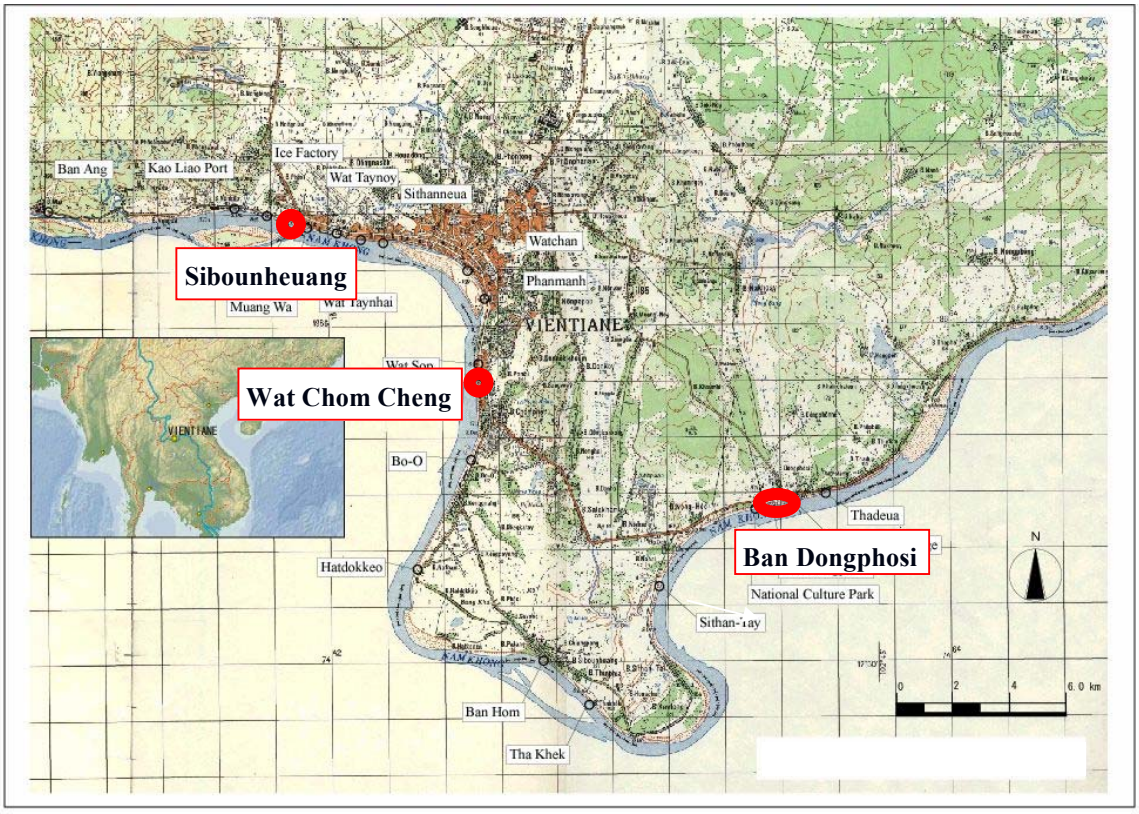


Figure 2.17 Location of 3 Pilot Work Sites

2.2.2 Site Condition for Pilot Works

Site condition at each Pilot Work site is as follows:

(1) Riverbank Type at Each Site

Condition of each Pilot Work site in December 2001 is as shown in Figure 2.18. The riverbank type is summarized in Table 2.10 and Figure 2.19.

Ban Dongphosi Site (December 2001)

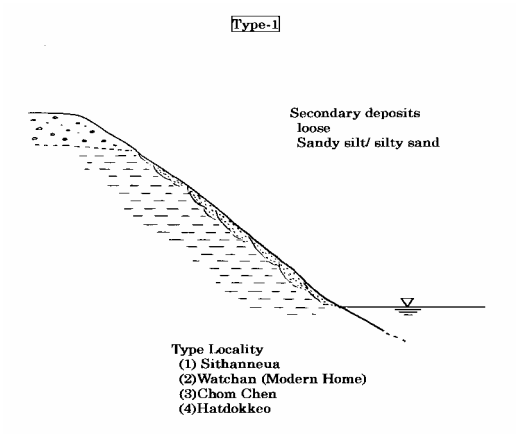
Wat Chom Cheng Site (December 2001)

Sibounheuang Site (December 2001)

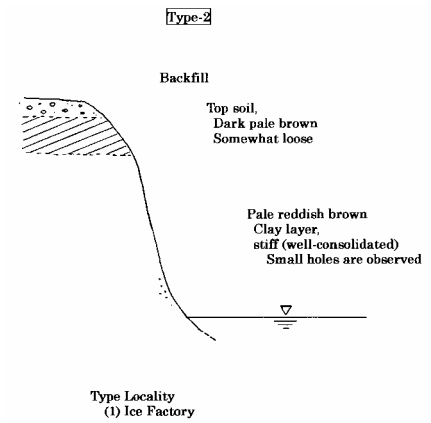
Figure 2.18 Condition of Pilot Work Sites

Table 2.10 Riverbank Type of Pilot Work Site

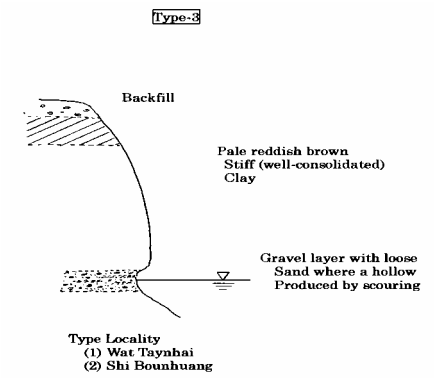
Type of riverbank	Characteristics	Corresponding Pilot Work site ( ): other similar site
1	-bank slope: 45 degree or less -secondary deposits: loose sandy silt/silty sand	**Wat Chom Cheng** (Sithanneua, Watchan, Hatdokkeo)
2	- bank slope: 65~90 degree -upper layer: dark pale brown, somewhat loose -lower layer: pale reddish brown clay layer, stiff -small holes are observed	(Ice Factory)
3	- bank slope: 65~90 degree - upper layer: pale reddish brown, stiff clay - lower layer: gravel layer with loose sand where hollows are produced by scouring	**Sibounheuang** (Wat Taynhai)
4	- upper steep portion: pale gray silty clay, moderate stiff - lower gentle: gravel layer (Vientiane gravel), rather strong resistance against erosion	**Ban Dongphosi** (Sithantai, Thadeua)



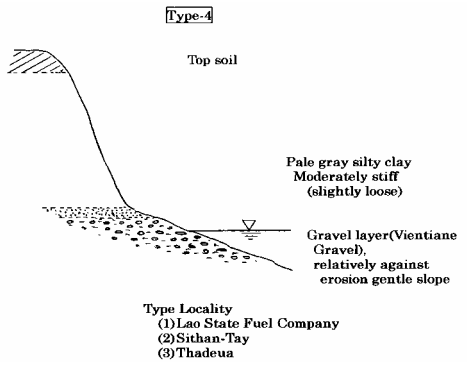
Type 1



Type 2



Type 3



Type 4

Note: Type number corresponds to that in Table 2.10

Figure 2.19 Type of Riverbank

(2) Design Flow Velocity

Design flow velocities (V_0) at Pilot Work sites are determined as shown in Table 2.11 by hydraulic analysis (Manning's coefficient of roughness (n) of 0.025 is applied).

Table 2.11 Design Flow Velocities of Pilot Works

Sine Name	Bank Elevation (EL.m) 1)	Discharge (m^3/s)	v_{avg} (m/s)	v_{toe} / v_{avg} 2)	V_{toe} (= v_0) (m/s)
1. Ban Dongphosi (1551.6km)	168.1	22,900	2.58	1.30	3.4
2. Wat Chom Cheng (1578.2km)	169.9	19,900	1.85	1.39	2.6
3. Sibounheuang (1589.0km)	170.1	18,100	2.30	1.15	2.6

Note: 1) above M.S.L. Ko Lak Datum. 2) Velocity concentration ratio

2.2.3 Facility Design of Pilot Works

(1) Design Criteria

The design criteria for Pilot Works are determined as shown in Table 2.12.

Table 2.12 Design Criteria of Pilot Works

Site Name	Design flow velocity (m/sec)	Low water level with 5-year return period (El. m)	Stone size
1. Ban Dongphosi	3.4	155.0	a) Rip-rap Stone: according to the formula of US Army Corps of Engineering b) Filling Stone: according to a experimental formula (Actual size should be 1.3 to 1.5 times of the critical size of stone)
2. Wat Chom Cheng	2.6	158.1	
3. Sibounheuang	2.6	158.9	

(2) Selection of Construction Type

The construction types in Table 2.13 are adopted for each Pilot Work site.

Table 2.13 Construction Type of Pilot Works

Site Name	Construction type
1. Ban Dongphosi	1) Riprap work, 2) Soda mattress work and 3) Coble stone with willow branch work
2. Wat Chom Cheng	1) (partial) Soda mattress work and 2) Wooden pile groin work
3. Sibounheuang	1) Log hurdle work, 2) Soda mattress work and 3) Cobble stone with willow branch work (covering lower bank)

(3) Design of Pilot Works

The design of three (3) Pilot Works is conducted according to the above-mentioned condition (1) and (2). The design is further reviewed and revised after the historical big flood in August 2002, and is incorporated into the description in Chapter 3. The drawings for three (3) Pilot Work sites are presented in Chapter 3.

2.2.4 Monitoring Program of Pilot Works

Monitoring of three (3) Pilot Works was conducted with the assistance of MCTPC counterpart, national university of Laos and local contractors mainly to confirm the effect of the works. The results are compiled in Chapter 5.

(1) Topographic and Hydraulic Condition

Monitoring program of the topographic and hydraulic condition at the sites is as shown in Table 2.14.

Table 2.14 Monitoring Program of Topographic and Hydraulic Condition

Monitoring Items	Site	Nos	Interval	2001	2002		2003		2004	
				Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season
Cross-sectional surveying	All Sites	3		–		–		–		
River water stage	All Sites		Everyday	—	—	—	—	—	—	—
Flow velocity and direction	All Sites	6		–	–	–	–	–	–	
Scoring depth	Wat Chom Cheng	2				–		–		

(2) Vegetation Condition

Monitoring program of vegetation condition is as shown in Table 2.15.

Table 2.15 Monitoring Program of Vegetation Condition

Monitoring Place	Monitoring Items	Unit	Quantities during Nov. 2002- Nov. 2004
Pilot work sites (3 sites)	Distribution of vegetation and flora	Time	2
	Planting of willow	Time	3
	Growth situation of willow	Time	12
Existing bank protection work sites (4 sites)	Distribution of vegetation and flora	Time	2
	Growth situation of willow	Time	7
Natural slope (1 site)	Distribution of vegetation and flora	Time	2
	Growth situation of willow	Time	3
Place where soda material was gathered	Growth situation of trees	Time	3

2.2.5 Construction Plan

Preparatory to the execution of the Pilot Works, the following items relating to the construction plan is preliminarily investigated and proposed as described in Chapter 3:

1. Construction method
2. Material procurement
3. Equipment procurement
4. Preliminary cost estimate
5. Implementation schedule

2.3 Field Survey for Pilot Work Design

For the designing of the Pilot Works, field survey and investigations at three (3) Pilot Work sites were conducted by local contractors during the period from January to February, 2002 under the supervision by the Study Team as follows:

2.3.1 Topographic Survey

Cross sections of the riverbanks (V=1:100, H=1:100) and topographic maps were prepared (Scale= 1:500, Contour= 1m pitch) with a quantity as shown in Table 2.16.

Table 2.16 Work Items of Topographic Survey

Site Name	Work Item	
	Cross Section Survey	Mapping
1. Ban Dongphosi	43 lines	42,000 m^2
2. Wat Chom Cheng	21 lines	24,000 m^2
3. Sibounheuang	16 lines	15,000 m^2

2.3.2 Velocity Measurement

Velocity measurements were carried out to obtain vertical/ plan distribution of current speed with a quantity as shown in Table 2.17.

Table 2.17 Work Items of Velocity Measurement

Site Name	Quantity
1. Ban Dongphosi	9 lines x 20 points/line = 180 points
2. Wat Chom Cheng	3 lines x 20 points/line = 60 points
3. Sibounheuang	3 lines x 20 points/line = 60 points

2.3.3 Geotechnical Investigation

(1) Soil Investigation

Geotechnical investigation was carried out to provide subsurface data for the facility design of the Pilot Woks. Investigation items are as follows:

1. Boring (115m in total) and in-situ tests, and
2. Various laboratory tests for clayey and sandy soil.

(2) Rock Piece Test

Rock piece tests of 20 samples at prospective quarry sites were conducted to know the basic properties of rock used for the bank protection materials.

2.3.4 Supporting Investigation for Initial Environmental Examination

Social/Natural environmental survey was conducted to obtain basic environmental data/information related to the Study Area including three (3) Pilot Work sites. The result is utilized as the basis of the environmental study described in Chapter 3.

3 EXECUTION OF PILOT WORKS

This Chapter 3 compiles the outline of the execution of riverbank protection pilot works (hereinafter referred to as "the Pilot Works") as a component of the Study. All the results are compiled in Volume 4, Supporting Report, Sector D -Execution of Pilot Works. The construction sequence is also compiled in Volume 3, Manual for Riverbank Protection, Sector B- Construction.

3.1 General

3.1.1 Outline

The Pilot Works at three (3) sites, namely, Ban Dongphosi, Wat Chom Cheng and Sibounheuang Sites as shown in Figure 3.1 were completed by the Study Team in May 2003. General of the work is as follows:

1. Scheme of execution: Sublet contract with the Study Team for JICA Development Study (Not JICA Grant Aid Project scheme)
2. Design & Supervision: JICA Study Team (in full cooperation with MCTPC/ DCTPC)
3. Contractor: Obayashi Corporation (selected by competitive bidding including local contractors)
4. Construction Period: January 2003 - May 2003 (5 months)
5. Construction Cost (engineering estimate): US$ 1,259,000 in total
   - i. Ban Dongphosi Site US$ 1,088,000 (approx. US$ 1,690/m)
   - ii. Wat Chom Cheng Site US$ 49,000 (approx. US$ 200/m)
   - iii. Sibounheuang Site US$ 122,000 (approx. US$ 810/m)

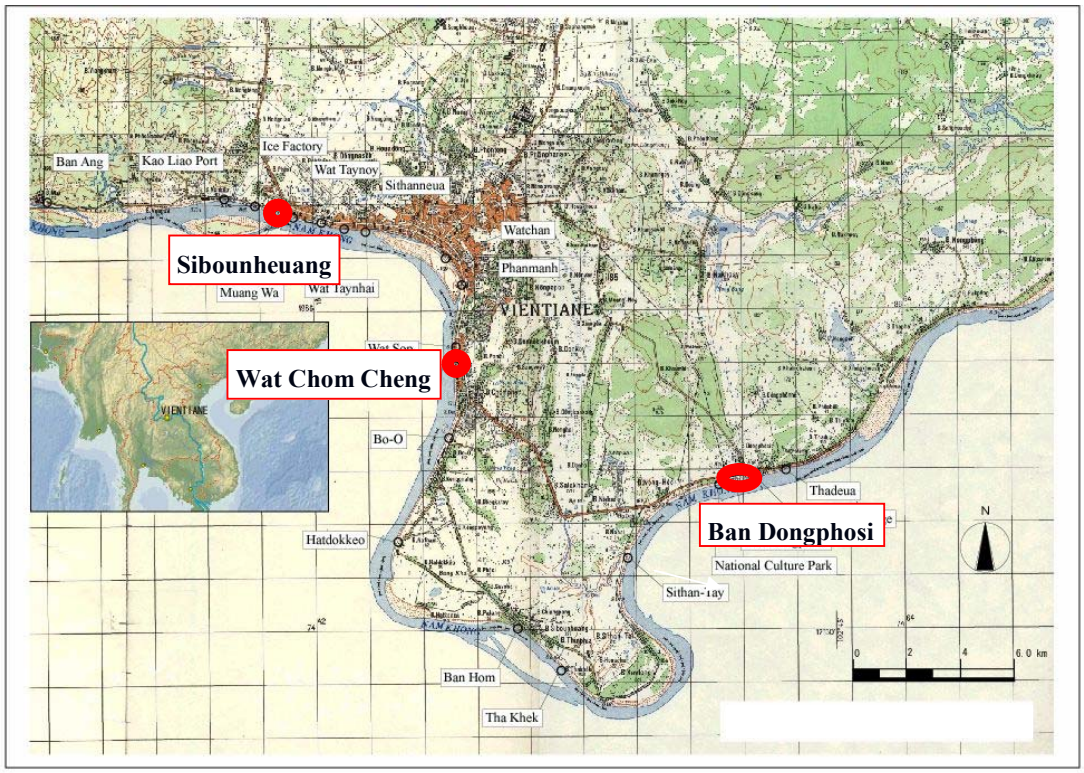


Figure 3.1 Location of 3 Pilot Work Sites

3.1.2 Upgrading of Specification at Ban Dongphosi Site

(1) Riverbank Erosion at Pilot Work Sites by August 2002 Flood

A historical big Mekong flood in August 2002 before the execution of the Pilot Works caused severe riverbank erosion in many Mekong stretches around Vientiane City as follows:

- The flood is the historical second biggest (H max = 170.64 m, MSL)
  <cf. the biggest in 1966 (H max = 170.75 m, MSL)>
- Ban Dongphosi: The average setback width eroded by the flood is around 2.3 m
  <cf. average setback width in ordinary year: around 0.5 m>
  - Upstream reaches (220 m) :1.2 m
  - Along oil stockpiling base (100 m) :2.2 m
  - Downstream reaches (330 m) :2.9 m
- Wat Chom Cheng: The riverbank was not eroded so much
- Sibounheuang:
  - Several limited points were eroded with the width of 3-5 m locally
  - However, the bank was not eroded so much generally (harder bank soil than that at Ban Dongphosi)

(2) Upgrading of Specification

- At Ban Dongphosi site, JICA decided to upgrade the facility design as follows after August 2002 flood taking into account the importance of oil stockpiling base located extremely close to the eroded vertical cliffy banks:
  - Additional backfill corresponding to the riverbank setback (average width = 2.3 m)
  - Partial reinforcement by stone covering (L=100 m at the front of oil stockpiling base)
- Wat Chom Cheng and Sibounheuang sites: original design is applied
- The execution of the works was rescheduled as a result of a series of careful discussion in JICA after August 2002 flood and the revision of the design:
  - Original schedule: November 2002 – March 2003 (5 months)
  - Actual schedule : January 2003 – May 2003 (5 months)

3.1.3 Technical Guidance for Soda Technique

The technical guidance for transfer proper construction method was conducted by a Japanese Soda (fascine) technique expert of the Study Team as follows:

- Period: February and March 2003
- Location: Construction sites of Pilot Works
- Items: 1) Soda Mattress work and 2) Cobble stone with willow branch work

3.2 Execution of Pilot Work at Ban Dongphosi Site

3.2.1 Outline

The pilot work at the site was completed in May 2003 based on the revised facility design upgraded in 2nd Work in Lao P.D.R. to cope with the severe erosion caused by August 2002

flood. After completion, willows will grow and will cover the surface of the slope. The photos before and after the execution are as shown in Figure 3.2. The outline of the work is summarized in Table 3.1.

Before construction (October 2002)

Just after construction (May 2003)

After rainy season (January 2004)

Figure 3.2 Completed Pilot Work at Ban Dongphosi Site

Table 3.1 Outline of Pilot Work at Ban Dongphosi Site

1. Total length of execution: 643 m
2. Riverbank type: a) upper steep portion: pale gray silty clay, moderate stiff b) lower gentle portion: gravel layer (Vientiane gravel), rather strong resistance against erosion
3. Design criteria: c) design flow velocity: 3.4 m/sec d) low water level with 5-year return period: 155.0 m, MSL
4. Construction type: e) Foundation work (rubble deposition) f) Foot protection work (Soda Mattress work) g) Slope protection work (Cobble stone with willow branch work)
5. Main points to note: h) Much amount of backfill is introduced to protect important properties, especially around the oil stockpiling base of Lao State Fuel Company. i) The slope protection work for peripheral part of the Company is designed to protect the foot of the steep cliff to avoid further setback due to undermining of the slope and to establish naturally stable slope with vegetation. j) The following upgrading of facility design is newly introduced after August 2002 flood • additional backfill corresponding to the riverbank setback eroded by the flood with an average width of 2.3 m • partial reinforcement by stone covering at the front of oil stockpiling base (L=100 m) k) After completion, willows will grow and will cover the surface of the slope.
6. Work items: l) preparatory works • temporary works and facilities • collection and transportation of materials m) foundation riprap works n) foot protection works by Soda Mattress • assembling of mattress (66 sheets) • installation of mattress o) earth works (backfill and embankment by river sand) p) slope protection works • cobble stone with willow branch works • partial reinforcement by stone covering (L=100 m) q) finishing works, and r) inspection of completion by the Study Team
7. Construction period: January 2003 - May 2003

3.2.2 Drawings

Drawings of the work are as shown in Figure 3.3.

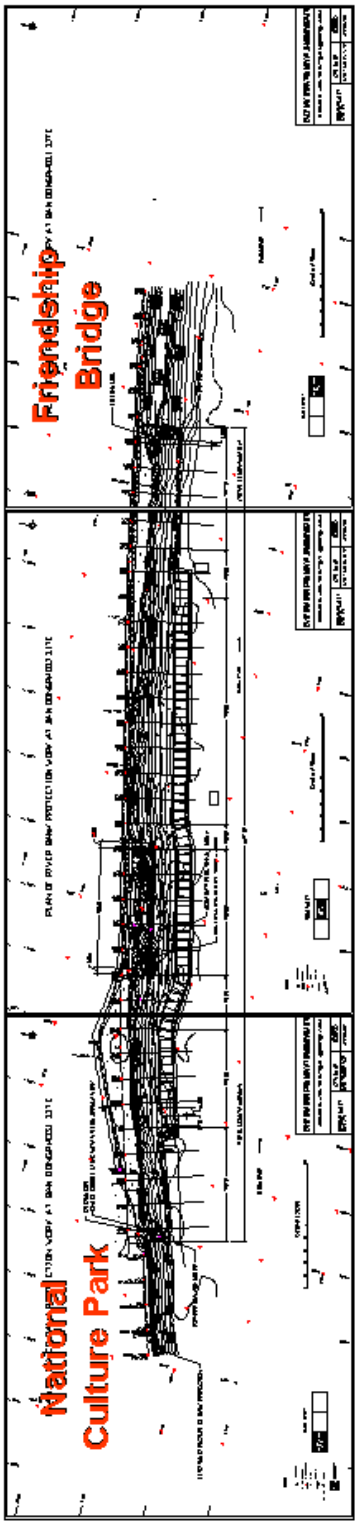


Figure 3.3 (1/3) Drawings of Ban Dongphosi Site

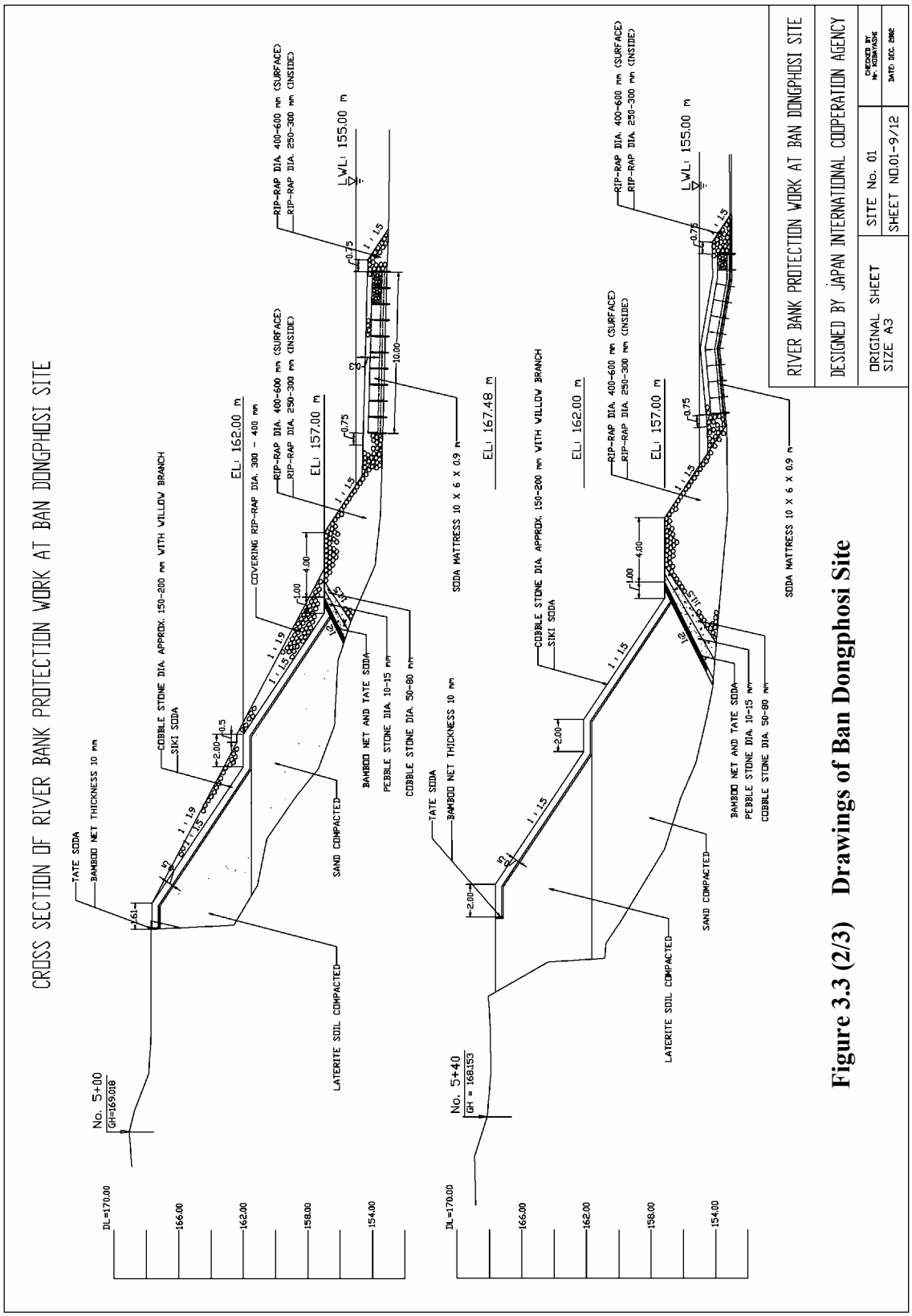


Figure 3.3 (2/3) Drawings of Ban Dongphosi Site

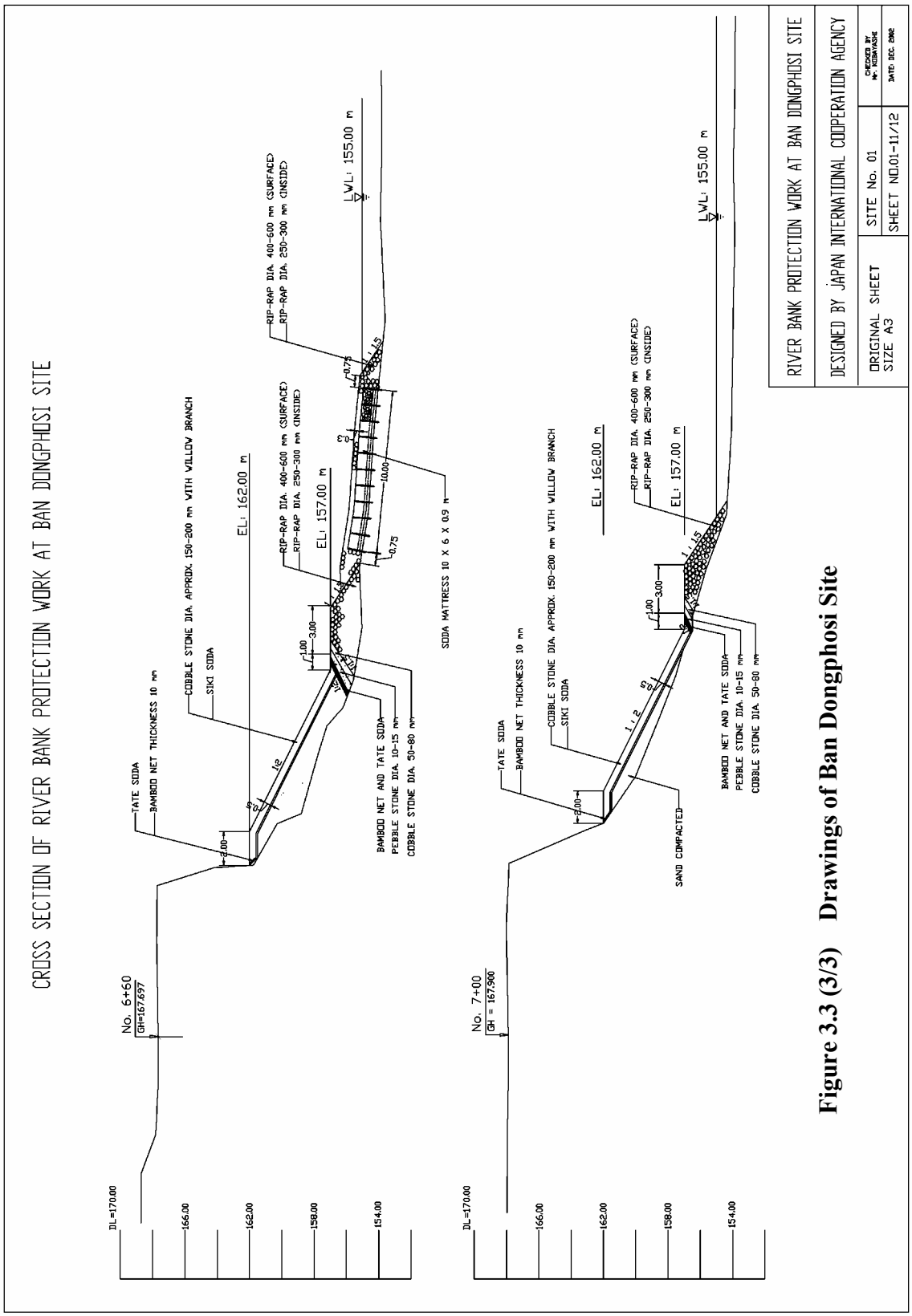
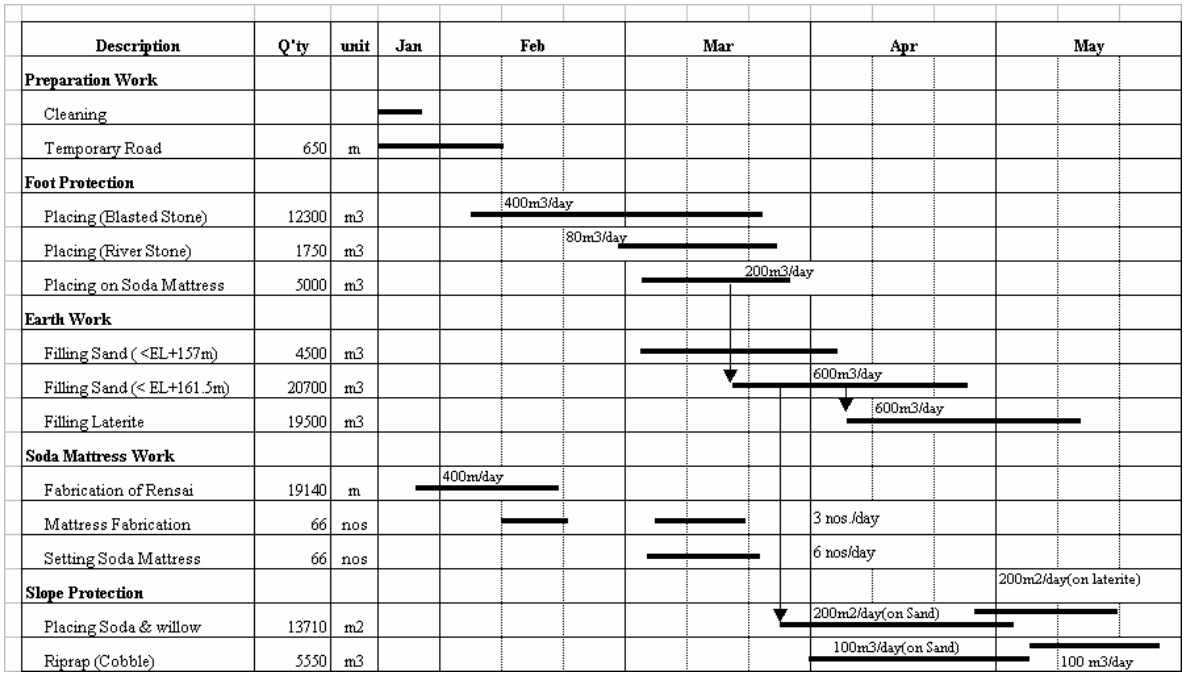


Figure 3.3 (3/3) Drawings of Ban Dongphosi Site

3.2.3 Construction Schedule

The Pilot Work was executed according to the schedule as shown in Table 3.2 from January to May, 2003.

Table 3.2 Construction Schedule of Ban Dongphosi Site



3.2.4 Construction Equipment and Materials

(1) Construction equipment

Main construction equipments and its working description utilized for the execution are listed in Table 3.3.

Table 3.3 Construction Equipment for Pilot Works

Item	Capacity	Working Description
Rensai Stand	2 lines	Rensai assembling
Backhoe	0.7 m3	Riprap, Earthwork, Piling
Truck	6-10 t	Transportation (Soda Material)
Dump Track	10 t	Transportation (stone, soil)
Clam shell	1.0 m3	Riprap, Depositing
Bulldozer	D5-D20	Earthwork
Rough Terrain Crane	30 t	Fabrication (Soda Mattress)
Crawler Crane	50 t	Setting Soda Mattress
Vibration Roller	8 t	Earthwork
Air Compressor	18 m3/min	Blasting
Drilling Machine	100 PS	Blasting (Quarry Site)
Flat Barge	150-250 t	Transportation, Work Space
Generator	10-60 KVA	Electricity Supply

(2) Materials

The main material used for the Pilot Works and its specification is summarized in Table 3.4.

Table 3.4 Construction Materials for Pilot Works

Item	Specification	Site Name
Soda Mattress (Foot protection work)		3 Sites
Soda	Length: 2.7m, 45cm rise peripheral 60cm 200cm rise peripheral…55cm	○
Taisya	Length:2.7m, ϕ 2～3cm at butt end ϕ 1.0cm at 2.7m rise, 25 twigs per bundle	○
Kogui	Length: 1.2m, ϕ 3～5cm at butt end	○
Rubble stones	ϕ 600～250 mm, ϕ 100～50 mm (inside)	○
Straw rope	ϕ 10 mm	○
Zinc-coated whip	#10	○
Zinc-coated whip	#12	○
Backfill (Slope protection work)		BD and SH
River sand & Gravel	< ϕ 80 mm, collected in the Mekong River	○
Laterite	Collected on Ban Dongphosi borrow pit	○
Pebble	ϕ 80～10 mm	BD
Cobble	ϕ 200～150 mm	○
Rubble	ϕ 600～400 mm (deposition)	BD
Rubble	ϕ 400～300 mm	○
Bamboo net	B=2.5 m L=2.5 m	○
Tate Soda	L=3.0 m, S=0.7 m	○
Cobble Stone with Willow Branch Work (Slope protection work)		BD and SH
Siki Soda	L=3.0 m, S=0.7 m	○
Taisya	L=3.0 m, 1 bundle =25 unit	○
Kogui (Short Pile)	L=1.2 m ϕ =4 cm	○
Willow	L=1.2 m, S=0.9 m	○
Cobble	ϕ =150 – 200 mm	○
Wooden Pile Groin Work (foot protection work)		WC
Wooden Pile	Length:4 – 6.0 m, tip end> ϕ 15 cm	○
Tie-beam	L=3.2 m, tip end> ϕ 9cm	○
Bolt	L=30 cm, d=13 mm	○
Zinc-coated whip	#12	○
Rip-Rap Work (Slope protection work)		WC
Rubble	ϕ 300～250 mm	○
Log Hurdle Work (slope protection work)		SH
Pile (Kogui)	Length:3.0m, tip end: ϕ 20 cm	○
Wailing log	Length:4.2m, tip end: ϕ 10 cm	○
Short pile	Length:1.5m, tip end: ϕ 10 cm	○
Bolt	L=30 cm, d=13 mm	○
Zinc-coated whip	#12	○
Nail	L=15 cm	○
Pebble	ϕ 150～50 mm	○
Tate Soda	T=20～30 cm	○
Bamboo Net	T=10 mm	○

Note for Site: ○: Applicable, BD (Ban Dongphosi), WC (Wat Chom Cheng), SH (Sibounheuang)

3.2.5 Construction Works

This sub-section describes the outline of each construction works at the site. The construction sequence of each works is compiled in Volume 3, Manual for Riverbank Protection.

(1) Preparatory works

- Temporary works and facilities:
  - 2 access road of 8m wide (national road - the site)
  - Soda Mattress stockyard (fabrication and stock)
  - A temporary office and workers houses
- Collection and transportation of materials (refer to Figure 3.4):
  - Stones: Nong Teng temporary quarry site, Ban Sakai quarry site
  - Gravel and sand: from market
  - Laterite: collected from the borrow pit located near Ban Dongphosi.
- Fascine material (Soda, Taisha and Kogui etc.) (refer to Figure 3.4):
  - collected in Nongpen Village located close to the site
  - transported by trucks (6-10 t) to the stockyard
  - some soda mattresses are transported from Kao Liao stockyard
- Fresh willow branch utilized for cobble stone with willow branch work:
  - Collected from the riverbank and sandbar near Ban Ang
  - Massive community on the sandbar located in front of Buddha Park is also available

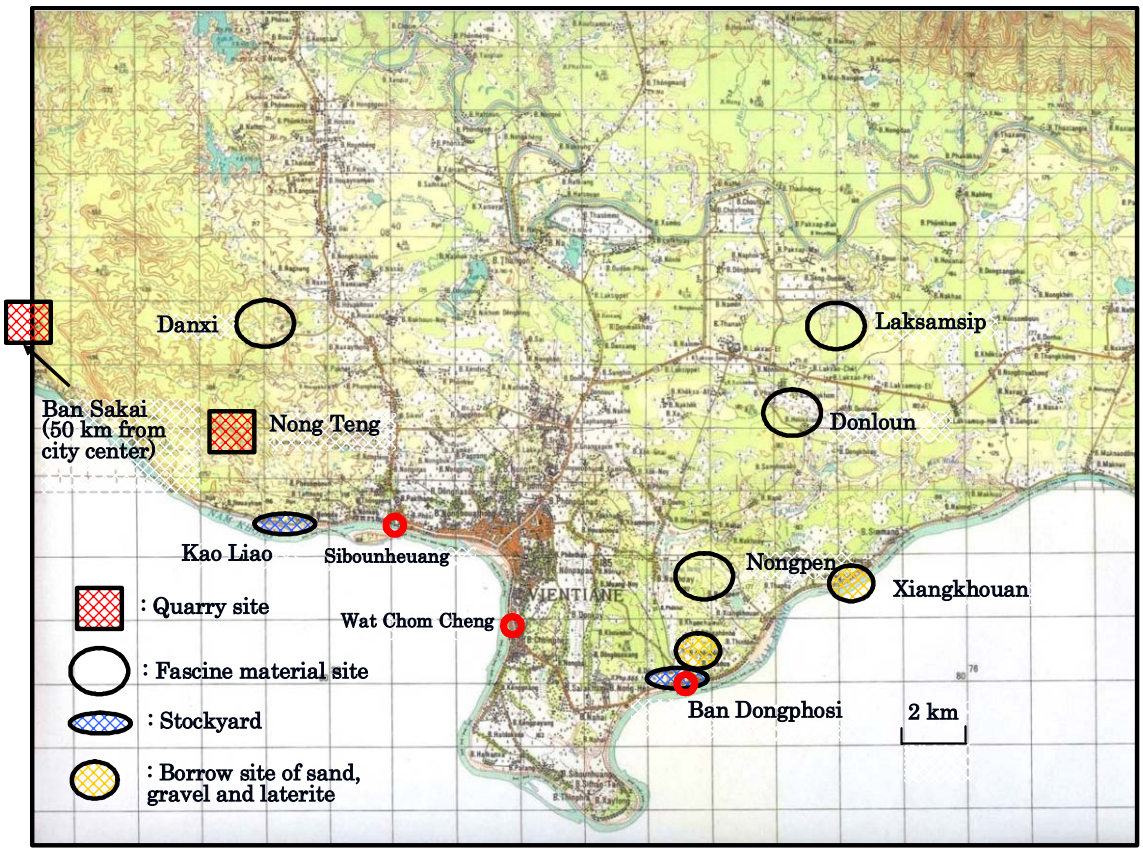


Figure 3.4 Location of Material Collection Sites

(2) Foundation works

- Riprap work is constructed as the foundation works of the slope to support the upper earth work (backfill) and slope protection work.
- Graded stones brought by dump truck from Ban Sakai quarry site and Nong Teng temporary quarry site are put on by using backhoe.
- Quantity
  - Stone dike (Crushed stone of dia. 250mm-600mm): 12,300m^3
  - Stone dike (gravel of dia. 50mm under): 1,800m^3
- The riprap foundation is temporary used as the construction road for setting Soda mattress.

(3) Foot Protection works

a) Assembling of Soda Mattress
- Outline: Soda Mattress consists of Soda (fascine), Rensai (brunch of fascine), Siki-Soda (fascine flooring), Sigara (hurdle work), and Chinseki (rubble stone).
- Construction Method:
  - On the lower lattice of Rensai, three layers of Siki-Soda are put on.
  - Upper lattice is put on the lower lattice and bound with rope and wooden pile driven at each node of the lattice to fix the structure.
  - Tie-twig hurdle work is made on it.
- Quantity: 66 sheets (10m x 6m x 0.9m)
- Almost all materials are produced locally.
- Soda mattress assembling work technique has been well transferred.

b) Installation of Soda Mattress (66 sheets)
- Outline: Assembled Soda mattresses are transported to the setting location and submerged by putting rubble stones on them.
- Construction Method:
  - Soda mattress is transported by crawler crane to the riverbank.
  - Using crawler crane, the mattress is placed on the river and fixed by anchors.
  - Putting rubble stones (V=5,200m^3) on the mattress by wire straw-basket and/or backhoe to submerge the mattress

(4) Earth works

- Outline:
  - The works is the backfill work to construct the embankment for the basis of slope protection work (cobble stone with willow branch work).
- Construction Method:
  - Trimming of slope and clearance
  - Transportation of the Mekong river sand (V=45,000 m^3) by dump truck
  - Filling the sand by backhoe and bulldozer
  - Moisture content arrangement
  - Compaction by bulldozer and vibration roller

- Comment: The embankment material above El. 161.5 m changed from laterite to sand due to be completed in desired period.

(5) Slope Protection Works

a) Cobble Stone with Willow Branch Works

- Outline:
  - The structure on the slope of sand embankment consists of Siki soda, Taisya (tie-twig) hurdle work, willow branch placing, river sand & gravel placing and cobble stone placing.
  - Riverbank covered by vegetation to create favorable natural environment shall be realized.
- Construction Method:
  - Compaction and furnishing of slope (A=13,700 m^2)
  - Piling Kogui
  - Laying Taisya for frame fence
  - Pounding & placing of river sand, gravel and willow branch in the frame
  - Placing cobble stone (about 4,200 m^3) in the frames

b) Partial Reinforcement by Stone Covering

- Outline:
  - Additional covering riprap to reinforce completed cobble stone with willow branch works taking into account the importance of oil tanks.
  - The slope gradient is 1:1.9 with a length of 100 m.
- Construction Method:
  - Transportation of crushed stone (V=1,400m^3) by dump truck
  - Placing the stone by backhoe
  - Stone adjustment placing on the slope by man-power

3.3 Execution of Pilot Work at Wat Chom Cheng Site

3.3.1 Outline

The pilot work at the site was completed in May 2003 based on the original design established in March 2002, 1st Work in Lao P.D.R (refer to Section 2.2). The photos before and after the execution are as shown in Figure 3.5. The outline of the work is summarized in Table 3.5.

Before construction (February 2002)

Just after construction (May 2003)

After rainy season (December 2003)

Figure 3.5 Completed Pilot Work at Wat Chom Cheng Site

Table 3.5 Outline of Pilot Work at Wat Chom Cheng Site

1. Total length of execution: 240 m
2. Riverbank type: s) bank slope: 45 degree or less t) secondary deposits: loose sandy silt/silty sand
3. Design criteria: a) design flow velocity: 2.6 m/sec b) low water level with 5-year return period: 158.1 m, MSL
4. Construction type: a) Foot protection work (wooden pile groin work, Soda Mattress) b) Slope protection work (wooden pile groin work)
5. Main points to note: a) Number of groin: 6 (3 of them are reinforced by Soda Mattress) b) Spacing of groins: 40 m (upper stretch), 60 m (downstream stretch) c) Length of the groin: 20m d) 3 rows of wooden piles is arranged in a hound's tooth with spacing of 1m
6. Work items: a) preparatory works • temporary works and facilities • collection and transportation of materials b) groin works • log pilling • assembling of soda mattress (9 sheets) • installation of soda mattress c) finishing works, and d) inspection of completion by the Study Team
7. Construction period: January 2003 - May 2003

3.3.2 Drawings

Drawings of the work are as shown in Figure 3.6.

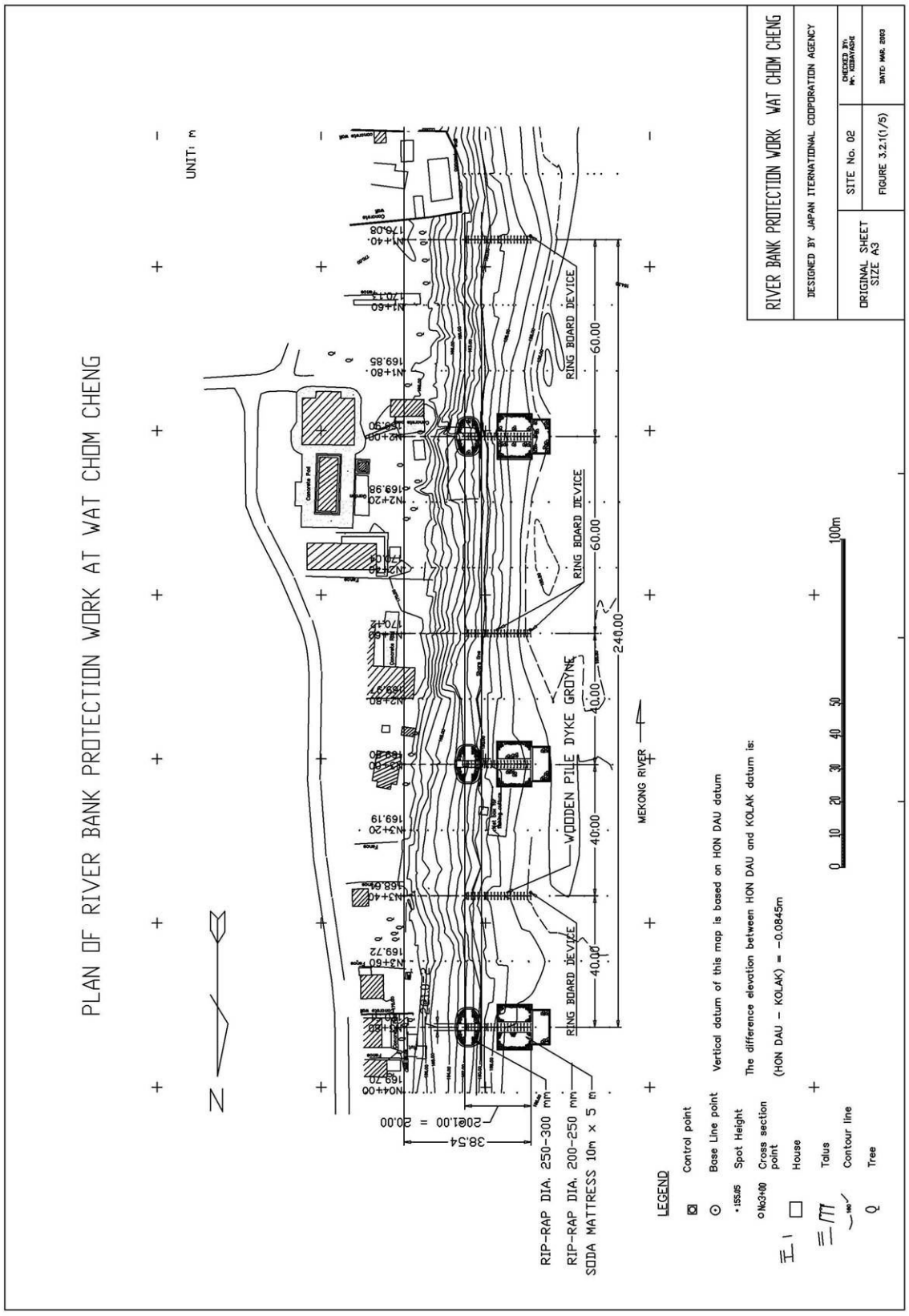


Figure 3.6 (1/2) Drawings of Wat Chom Cheng Site

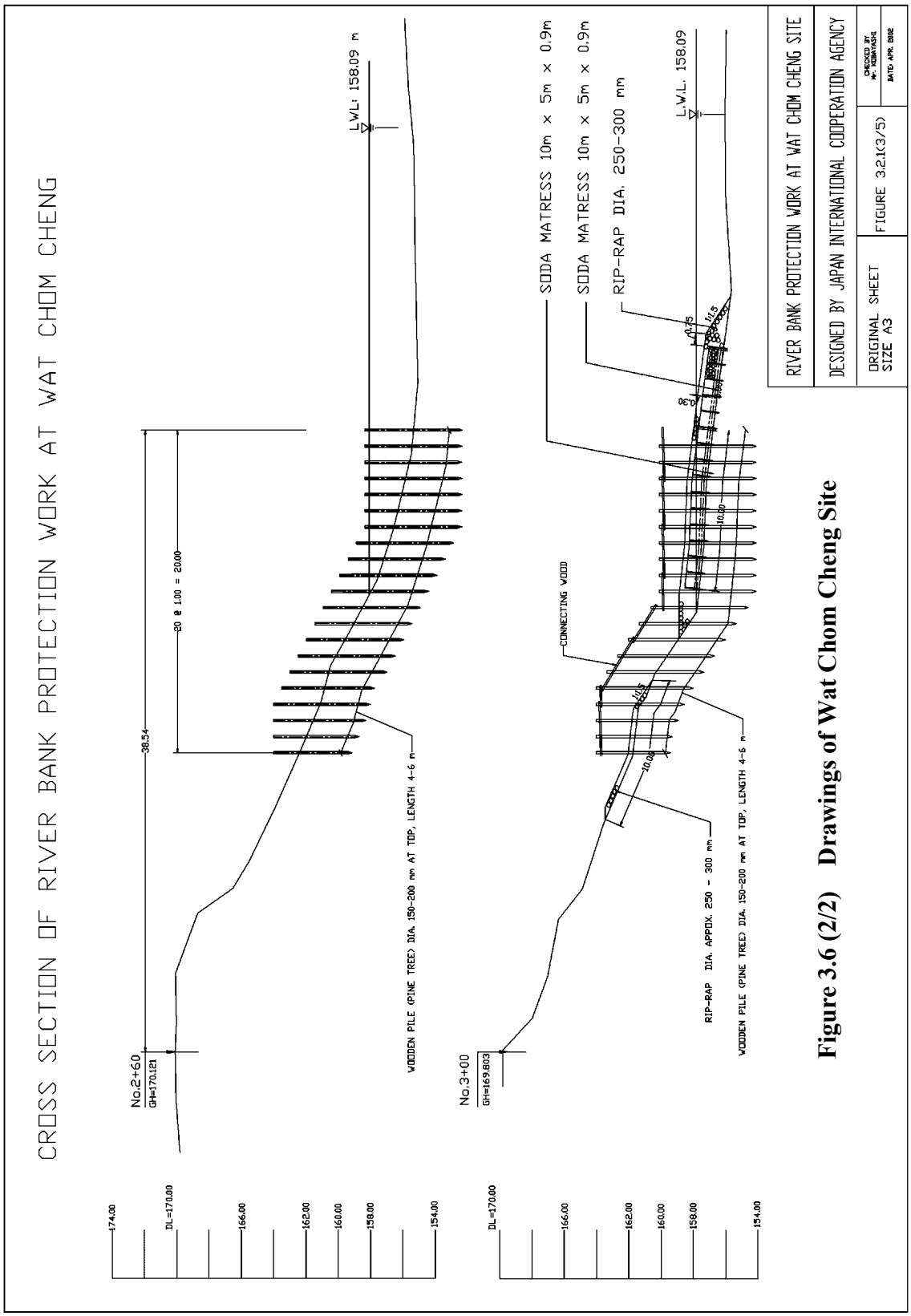


Figure 3.6 (2/2) Drawings of Wat Chom Cheng Site

3.3.3 Construction Schedule

The Pilot Work was executed according to the schedule as shown in Table 3.6 from January to April, 2003.

Table 3.6 Construction Schedule of Wat Chom Cheng Site

Description	Q'ty	unit	Jan	Feb	Mar	Apr
Wooden Piling Work						
Wooden pilling	378	nos			30nos/day	
Connecting Wooden Pile	360	m				
Stone Work						
Riprap for slope protection	100	m3				
Riprap on Soda Mattress	560	m3				120 m3/day
Soda Mattress Work						
Fabrication of Rensai	2,253	m		200 m/day		
Mattress Fabrication	9	nos		1no./day		
Setting Soda Mattress	9	nos				2 nos/day

3.3.4 Construction Equipment and Materials

Construction equipment and materials utilized for the site is as mentioned in Section 3.2 (4).

3.3.5 Construction Works

This sub-section describes the outline of each construction works at the site. The construction sequence of each works is compiled in Volume 3, Manual for Riverbank Protection.

(1) Preparatory works

- Workstation is set up at Kao Liao site
- All the work is performed by barge from the Mekong River.
- Collection and transportation of fascine materials are:
  - collected in Donloun and Laksamsip Villages
  - transported by trucks (6-10 t) to the stockyard
- Wooden logs are purchased in market. The log is cut and sharpened as pile.
  - A flat barge transports wooden piles and soda mattresses to the site.

(2) Groin works

a) Log piling

- Outline: The piling is permeable dyke groin to reduce river flow velocity and sifting current direction offshore-wards to protect riverbank between groins.
- Construction Method
  - 378 wooden piles (L=6 m) are driven by backhoe on barge

- Wooden pile of every other groin is connected with tie-beam (L=3.2 m).
- Riprap is placed on the slope around connecting piles

b) Assembling of Soda Mattress

- Outline and Method: the same as that at Ban Dongphosi site <refer to 3.2 (5) 3)>
- Quantity: 9 sheets (10m x 5m x 0.9m)

c) Installation of Soda Mattress (9 sheets)

- Outline:
  - Assembled Soda mattresses are transported to the setting location and submerged by putting rubble stones on them.
  - All the installation work is conducted on the water.
- Construction Method:
  - Floating Soda mattress is towed by boat from Kao Liao stockyard into the site.
  - Using the boat and manpower, the Soda mattress is placed on the surface of river water and fixed by anchors.
  - The mattress is submerged by putting rubble stones on them by a backhoe on a barge

3.4 Execution of Pilot Work at Sibounheuang Site

3.4.1 Outline

The pilot work at the site was completed in April 2003 based on the original design established in March 2002, 1st Work in Lao P.D.R (refer to Section 2.2). The photos before and after the execution are as shown in Figure 3.7. The outline of the work is summarized in Table 3.7.

Before construction (December 2001)

Just after construction (April 2003)

After rainy season (December 2003)

Figure 3.7 Completed Pilot Work at Sibounheuang Site

Table 3.7 Outline of Pilot Work at Sibounheuang Site

1. Total length of execution: 156 m
2. Riverbank type: a) bank slope: 65~90 degree b) upper layer: pale reddish brown, stiff clay c) lower layer: gravel layer with loose sand where hollows are produced by scouring
3. Design criteria: a) design flow velocity: 2.6 m/sec b) low water level with 5-year return period: 158.9 m, MSL
4. Construction type: a) Foundation work (log hurdle work), b) Foot protection work (Soda Mattress work), and c) Slope protection work (earthwork, Cobble stone with willow branch work).
5. Main points to note: a) The principle design concept is the same as IDI Japan's test project, i.e., to protect the foot of slope by foot protection work b) The slope protection work is designed to cover the possible notch formation part to avoid undermining.
6. Work items: a) preparatory works • temporary works and facilities • collection and transportation of materials b) foundation work (log hurdle works) c) earth works (embankment) d) foot protection works (Soda Mattress: 23 sheets) • assembling of mattress • installation of mattress • toe rubble deposition e) slope protection works for lower bank (cobble stone with willow branch works) f) finishing works, and g) inspection of completion by the Study Team
7. Construction period: January 2003 - April 2003

3.4.2 Drawings

Drawings of the work are as shown in Figure 3.8.

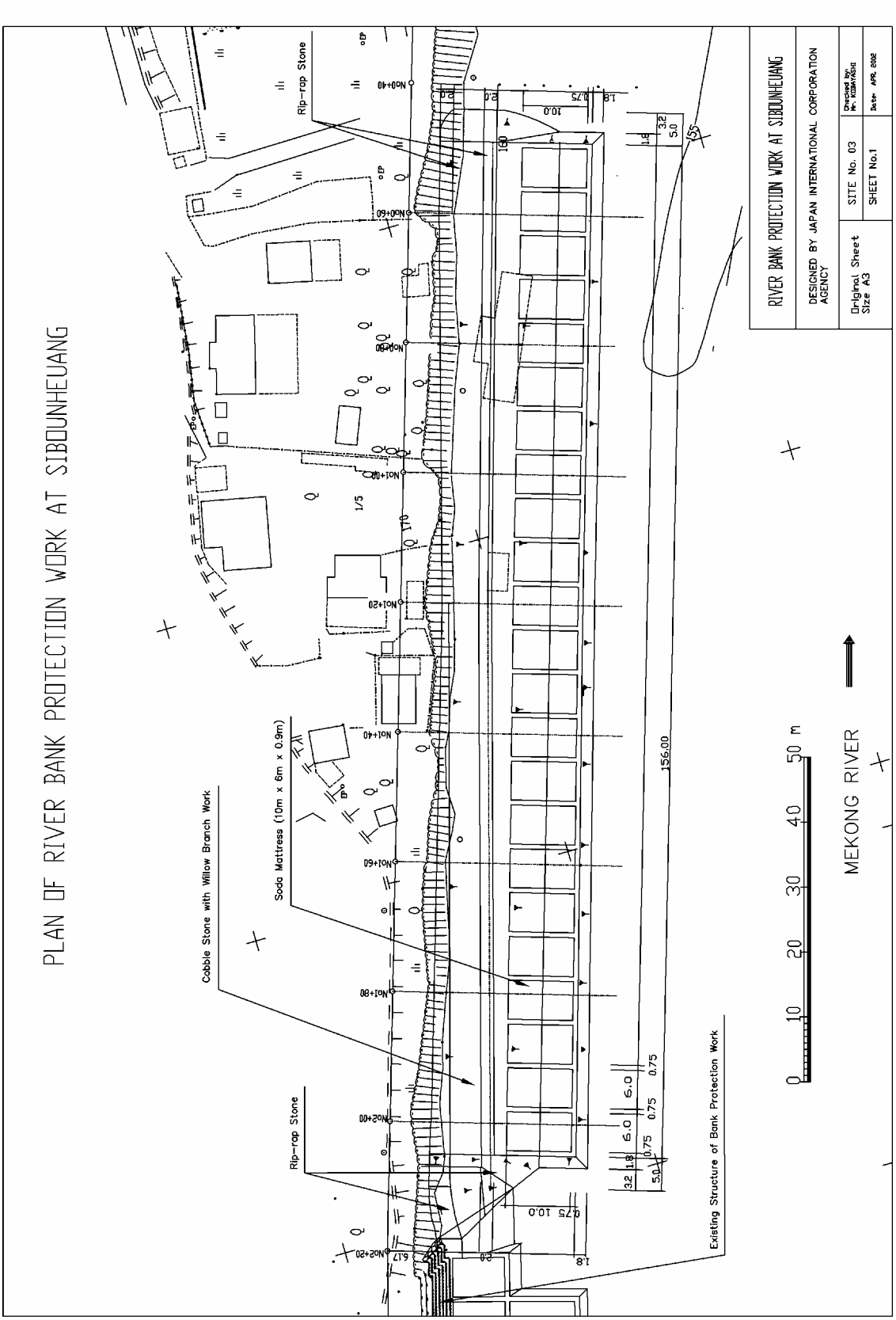


Figure 3.8 (1/2) Drawings of Sibounheuang Site

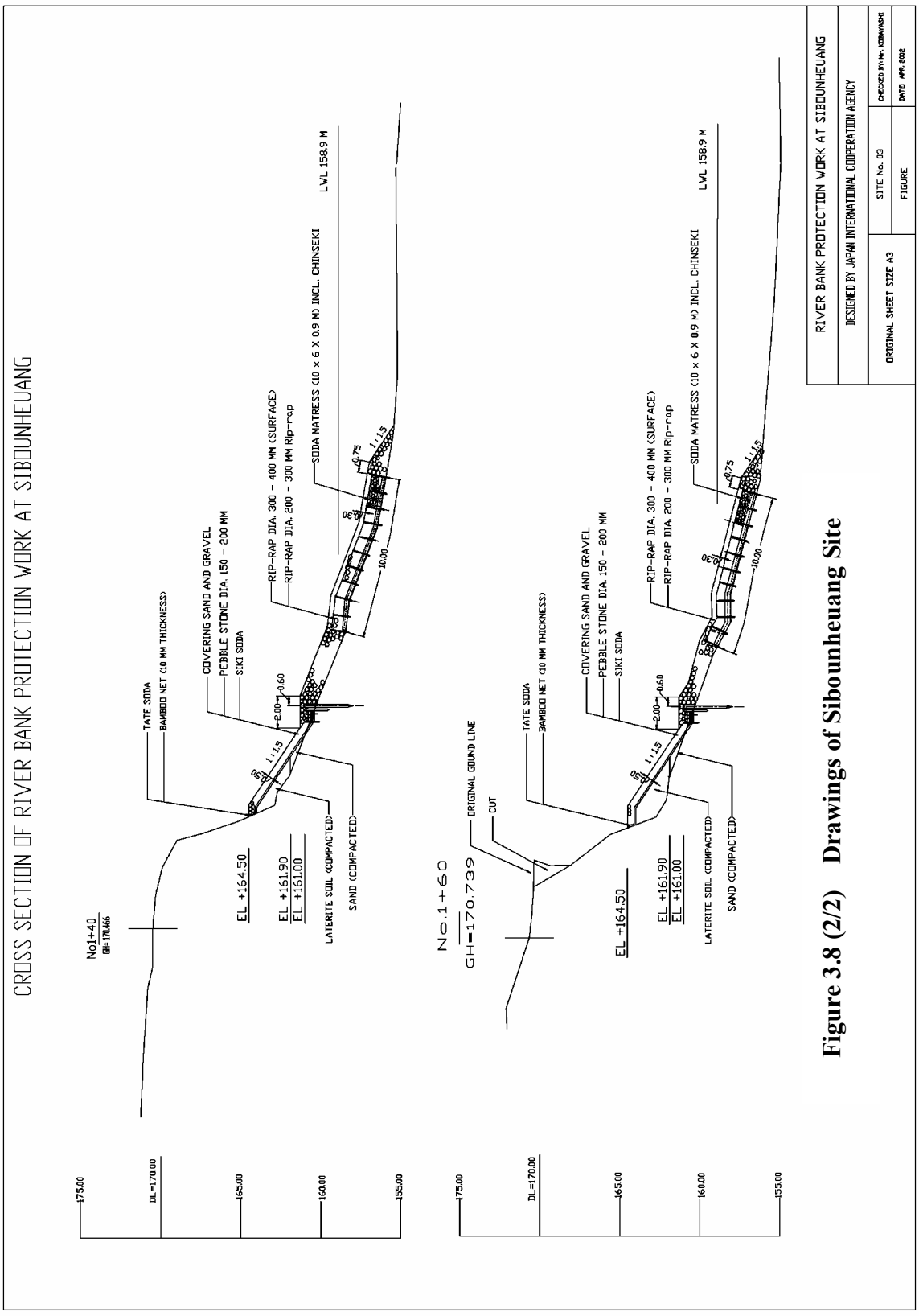


Figure 3.8 (2/2) Drawings of Sibounheuang Site

3.4.3 Construction Schedule

The Pilot Work was executed according to the schedule as shown in Table 3.8 from January to April, 2003.

Table 3.8 Construction Schedule of Sibounheuang Site

Description	Q'ty	unit	Jan	Feb			Mar			Apr		
Wooden Piling Work												
Log Hurdle (L=3m)	78	nos			20nos./day							
Log Hurdle (L=1.5m)	770	nos				100nos./day						
Earth Work												
Filling Sand	270	m3						200m3/day				
Filling Laterite	660	m3						200m3/day				
Slope Protection												
Protection with soda material	1100	m2						200m2/day				
Placing Riprap	200	m3						200m3/day				
Soda Mattress Work												
Fabrication of Rensai	6750	m			200m/day							
Mattress Fabrication	23	nos		1 set/day							2 set/day	
Setting Soda Mattress	23	nos							4set/day			
Riprap on Soda Mattress	2400	m3							170m3/day			

3.4.4 Construction Equipment and Materials

Construction equipment and materials utilized for the site is as mentioned in Section 3.2 (4).

3.4.5 Construction Works

This sub-section describes the outline of each construction works at the site. The construction sequence of each works is compiled in Volume 3, Manual for Riverbank Protection.

(1) Preparatory works

The preparatory works at the site is the same as that for Wat Chom Cheng site <refer to 3.3 (5)>

(2) Foundation works

- Outline
  - Log hurdle work is constructed as foundation work to support slope protection work.
  - The work is composed of primary log piling (2m interval), secondary (short) piling (0.2 m interval), connecting beam and cobbles placed behind log hurdle as back-fill.
- Construction Method
  - Primary pile (L=3 m) is driven by backhoe set on barge.
  - Secondary piling (L=1.5 m) and connecting beam (L=4.2 m) setting is done by manpower.

  - Back-filling of cobble stones are done by Backhoe.
- Quantity: 77 primarily logs, 760 secondary logs

(3) Foot protection works

a) Installation of Soda Mattress
- Outline and Method: the same as that at Ban Dongphosi site <refer to 3.2 (5) 3)>
- Quantity: 23 sheets (10m x 6m x 0.9m)

b) Toe Rubble Deposition
- Outline
  - The work is done around log hurdle work and conjunction to Soda mattress to reinforce stability of earth embankment.
  - In addition, this functions as continuous protection work including Soda mattress, log hurdle work and cobble stone with willow branch works.
- Construction Method
  - Stone material (V=2,400 m^3) and construction equipment transported by barges
  - Placing and filling the material by a backhoe on the barge
  - Stone adjustment by manpower on the ground and under the water surface

(4) Earth Works

Outline and Method:
- The same as that for Ban Dongphosi site fundamentally <refer to 3.2 (5) 4)>
- The material (river sand (V=270 m^3) and laterite (V=520 m^3)) and construction equipment are transported by barges.
- The compaction work is conducted from the backhoe on the barge.

(5) Slope Protection Works

a) Cobble Stone with Willow Branch Works
- Outline and Method:
  - The same as that for Ban Dongphosi site fundamentally <refer to 3.2 (5) 5)>
- Quantity
  - Crushed cobble (V=200m^3)
  - Siki soda, Taisya, Kogui, willow branch (A=1,100m^2)

3.5 Preliminary Environmental Impact Assessment

EIA is not required officially, since the pilot works are not the major projects defined in Environmental Protection Low of Lao P.D.R. Prior to the construction, Pre-EIA for the pilot works including questionnaire survey by local consultant was conducted by the Study Team in January - February 2003. Pre-EIA proves that the pilot works have no serious environmental impact potentially as follows, since the works are conducted to create favorable river environment (refer to Table 3.9):

1. During construction stage: Some check items are B (low negative impact) or C (unknown impact), however, most of check items are D (no impact).
2. Operation/maintenance stage: All check items are D (no impact)

Table 3.9 Summary of Pre-EIA for Pilot Works

Check Item / Site Name	During Construction			Operation/ Maintenance Stage		
	Ban Dongphosi	Wat Chom Cheng	Sibounheuang	Ban Dongphosi	Wat Chom Cheng	Sibounheuang
Social Environment						
Resettlement	D	D	D	D	D	D
Economic Activity	C	C	C	D	D	D
Traffic and public facilities	B	B	B	D	D	D
Split of communities	D	D	D	D	D	D
Cultural property	D	C	C	D	D	D
Water rights, Right of common	D	D	D	D	D	D
Public health condition	D	D	D	D	D	D
Waste	B	B	B	D	D	D
Hazard	B	D	D	D	D	C
Natural Environment						
Topography and geology	D	D	D	D	D	D
Soil erosion	B	B	B	C	C	C
Groundwater	D	D	D	D	D	D
Hydrological situation	D	D	D	D	D	D
Coastal zone	D	D	D	D	D	D
Flora and fauna	B	B	B	D	D	D
Landscape	D	D	D	B	D	D
Public Nuisance						
Air pollution	B	B	B	D	D	D
Water pollution	D	D	D	D	D	D
Soil contamination	D	D	D	D	D	D
Noise and vibration	C	B	B	D	D	D
Ground subsidence	D	D	D	D	D	D

Assessment: A: High Negative Impact, B: Low Negative Impact, C: Unknown Impact, D: No Impact

4 TEST OF SIMPLE VEGETATION RIVERBANK PROTECTION WORKS

4.1 Outline

High-cost riverbank protection works is unrealistic measures for the banks forming continuous vertical cliffs with low important riverine area. Simple vegetation riverbank protection works might be the possible measures to fix such bank soil where some sedimentation is found in the dry season. The implementation cost of the vegetation works is extremely low, though it requires several years before the work effects. Accordingly, the test works of vegetation work were executed in January - May 2003 in assistance with National University of Laos.

4.2 Execution of Test Works

4.2.1 Site Selection

Location of the relating sites are as follows and shown in Figure 4.1

- Test work site: Nongheo (60 x 8 m) and Chom Cheng (24 x 6 m)
- Willow material collection site: Culture park and near Japanese ambassador house
- Soda material collection site: Danxi and Nongpen

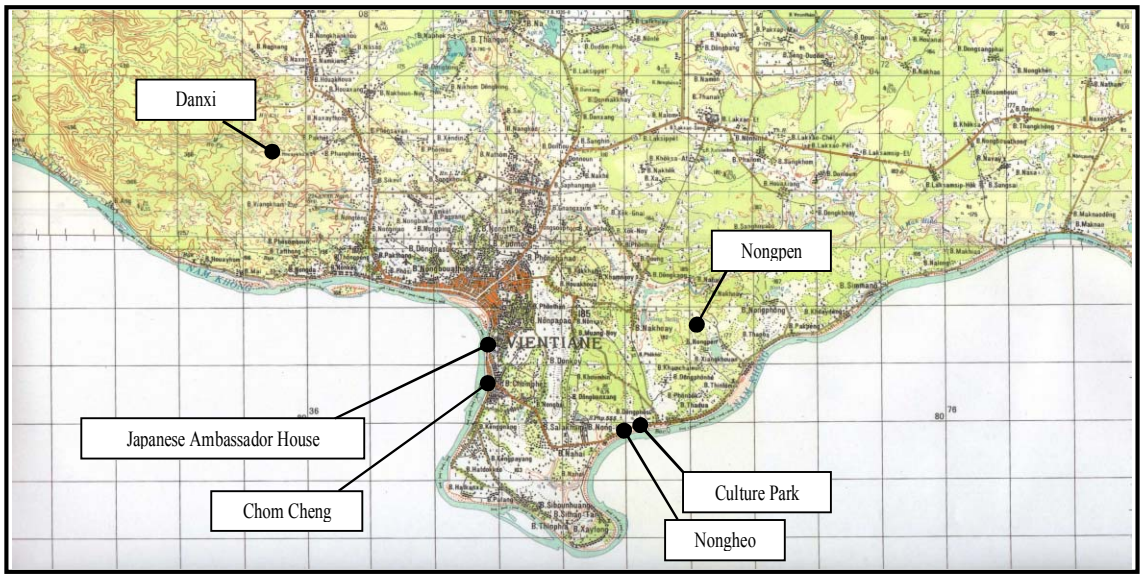


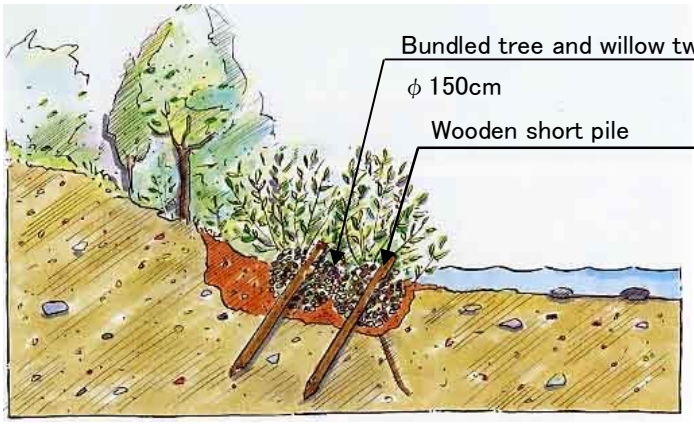
Figure 4.1 Location of Test Works and Relating Sites

4.2.2 Willow Planting Method

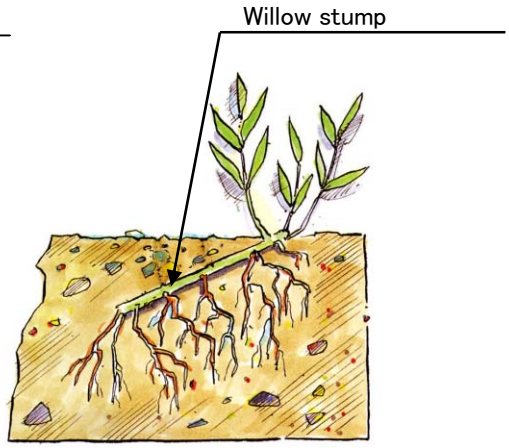
The test was conducted by four methods as follows and shown in Figure 4.2;

1. Bundled tree works: To bundle tree and willow twigs by strong wire, then to fix them by wooden short piles.
2. Soda-Net works: To make Soda-net of tree and willow twigs, wooden short piles.
3. Cutting works: To plant willow stump directly.
4. Seedling works: To plant willow seedling grown in pollybag.

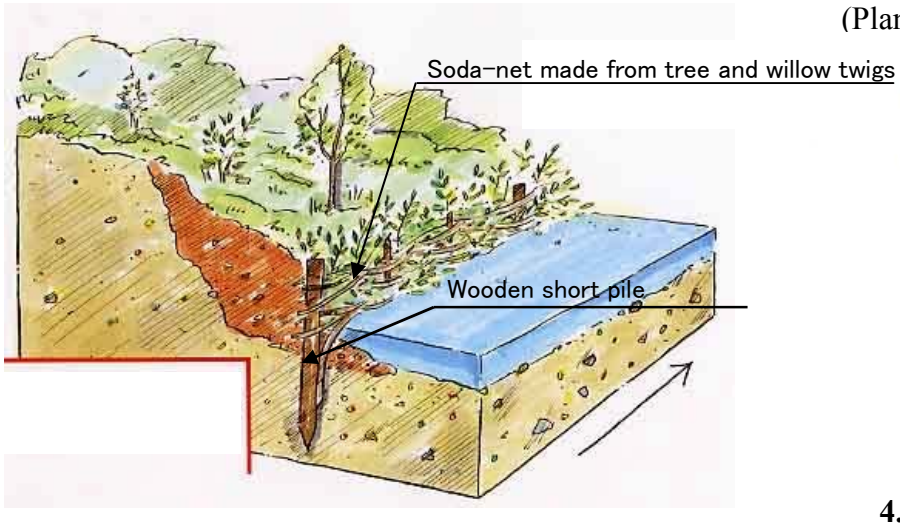
Willow was planted as water level goes down from January to May, since water is needed for willow appearing.



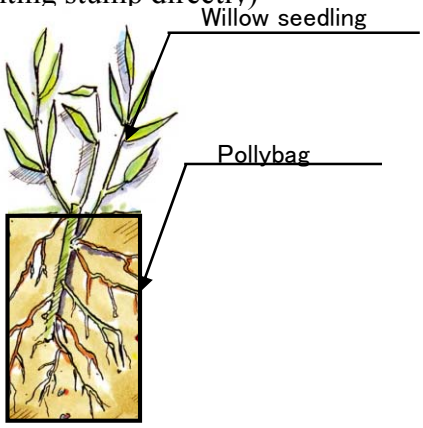
1. Bundled Tree Works



3. Cutting Works
(Planting stump directly)



2. Soda-Net Works



4. Seedling Works
(Planting Seedling grown in pollybag)

Figure 4.2 Methods of Planting Willow

Willow species utilized for the test work are Kok Khai and Khai Nun as shown in Figure 4.3.

Kok Khai *(Polyalthia corticosa)*

Khai Nun *(Eugenia fluviatilis)*

Figure 4.3 Willow Species for Test Works

4.2.3 Design of Test Sites

The test works were executed according to the design as shown in Figures 4.4 to 4.5 for Nongheo site (The design at Chom Cheng site is similar to that at Nongheo).

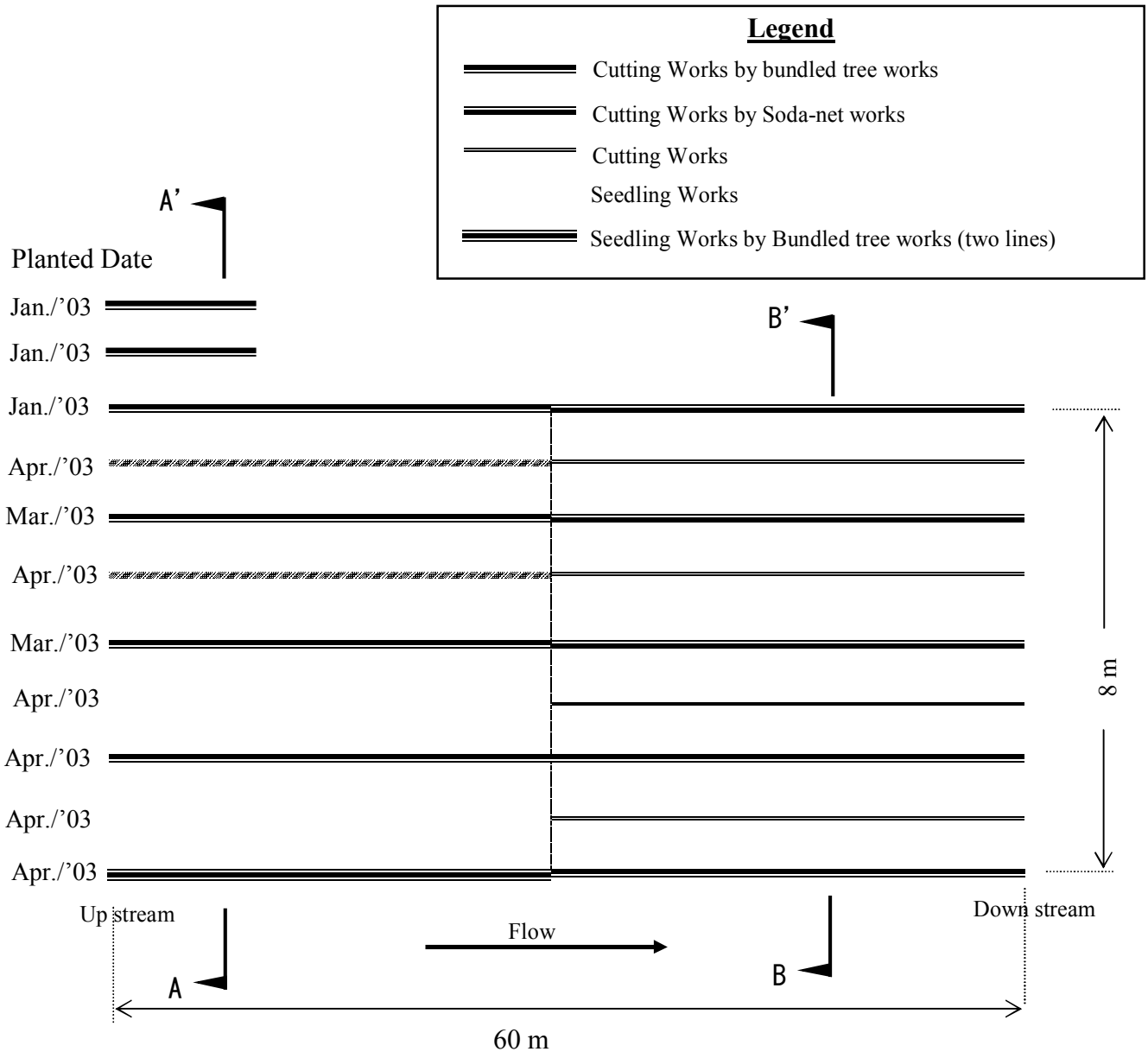
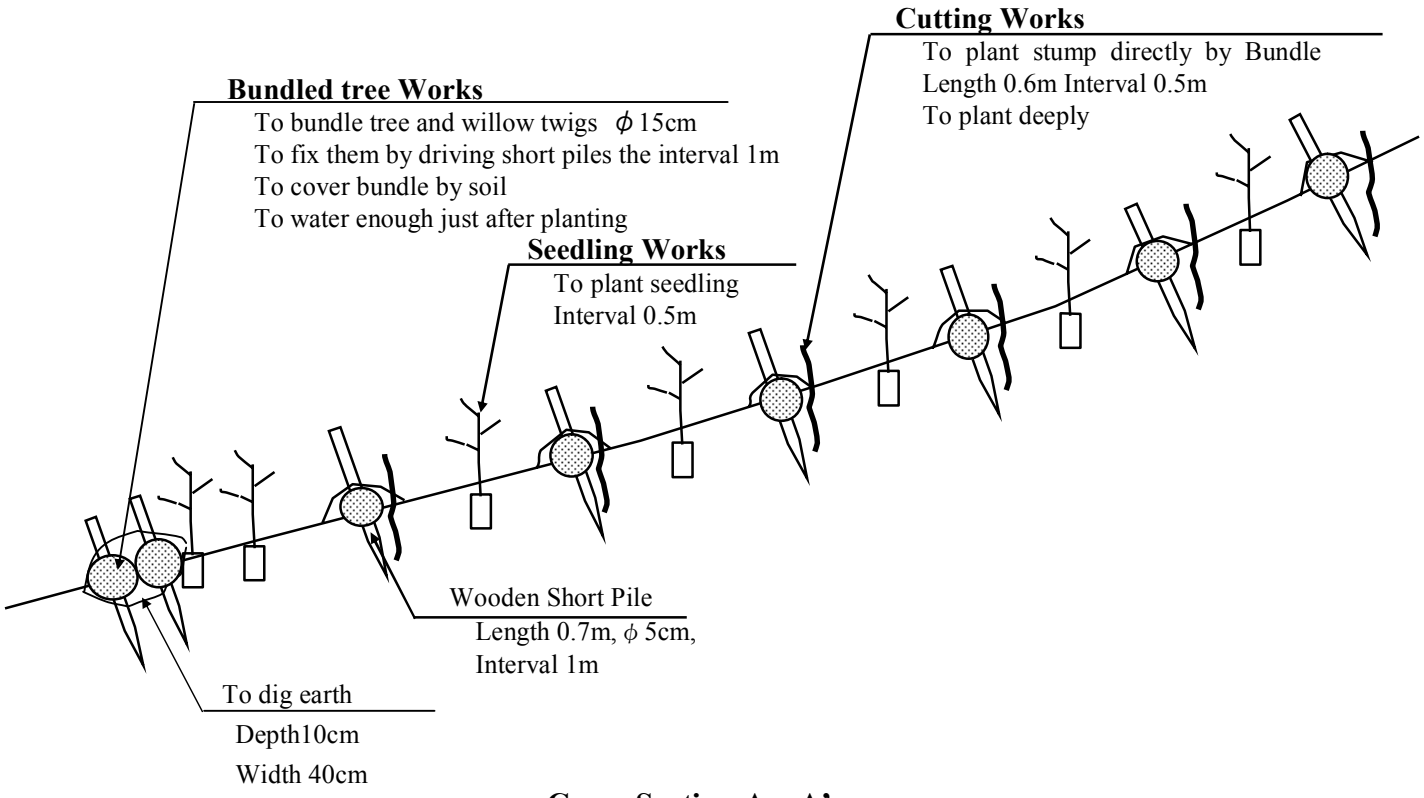
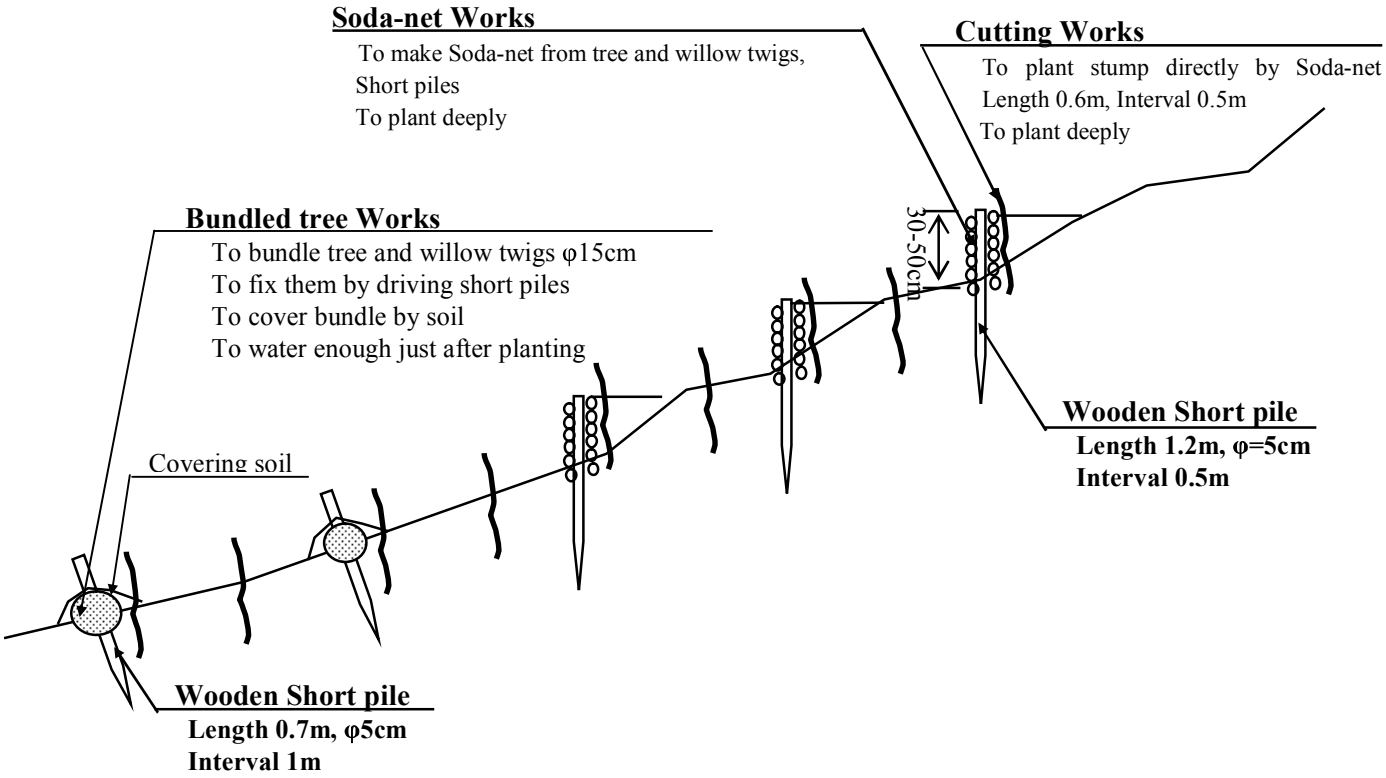


Figure 4.4 Plan of Test Site at Nongheo



Cross-Section A – A'



Cross-Section B –B'

Figure 4.5 Cross-section at Nongheo Site

4.3 Monitoring of Test Works

4.3.1 Monitoring Program

Monitoring of the test works was conducted according to the program shown in Table 4.1.

Table 4.1 Monitoring Items and Schedule

Monitoring Place	Monitoring Items	Unit	Q'ty	2003												2004											
				1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Nongheo	Planting willow	Time	1	—	—	—	—	—																			
	Growth situation of willow	Time	1													—											
	Reinfoceing soda fence(including willow)	Time	1														—										
Chom Cheng (Next Pilot work site)	Planting willow	Time	1	—	—	—	—	—																			
	Growth situation of willow	Time	1													—											

4.3.2 Monitoring Result

The survival rate of the planted willow at Nongheo site (500 seedling and 500 stumps) and Chom Cheng site (104 seedling and 104 stumps) is as shown in Table 4.2. The growth performance is as shown in Table 4.3. The root growth performance is as shown in Table 4.4. Situation of willow survived in December 2003 is shown in Figure 4.6.

Table 4.2 Survival Rate of Planted Willow

Sites	Survival Rate	
	Seedling	Stump Directly
Nongheo*	44%	23%
Chom Cheng	2,88%	6,73%

Table 4.3 Growth Performance of Planted Willow

Sites	Stump Directly (mean)		Seedling (mean)		Branch (mean)	
	D (mm)	H (cm)	D (cm)	H (cm)	L (cm)	No.
Nongheo	3.6	17.7	3.3	19.1	24.0	4.8
Chom Cheng	2.6	14.6	2.8	21.4	21.5	4.2

Table 4.4 Root Growth Performance of Planted Willow

Sites	Seedling		Stump Directly	
	Main root	Small root	Main root	Small root
Nongheo	No.= 3-10 roots D=0,1-0,9 Cm Length= 5-35 cm	No.= 16-75 roots D= very small Length=0,1-13 cm	No.= 3-10 roots D= 0,1-0,9 Cm Length= 5-55 cm	No.= 6-56 roots D= very small Length= 0,1-13 cm
Chom Cheng	No.=3-12 roots D=0,1-0,9 Cm Length= 5-75 cm	No.=13-86 roots D= very small Length=0,1-13 cm	No.= 3-10 roots D= 0,1-0,9 Cm Length= 5-35 cm	No.= 16-75 roots D= very small Length= 0,1-10 cm

Upstream side at Nongheo site
Two planting methods were applied, bundle tree with willow branches and seedling.

Downstream side at Nongheo site
Two planting methods were applied, soda-net made of soda and willow branch and stump directly planting.

Chom Cheng site
Soda-net eroded due to too soft earth

Figure 4.6 Situation of Planted Willow Survived (in December 2003)

4.3.3 Conclusion

The conclusion of the test work is as follows, further monitoring is required, though:
- 1) Bundled tree works, 2) Soda-net works and 3) seedling works are available.
- 1) Cutting works and 2) stump directly planting are available if watering could be continuously done for a month after planting.
- In order to ensure the success, it is necessary to grow more to form willow community.

It is important for willow planting as follows:
- To plant deeply by stump directly planting and by using Soda-net
- To cover bundle tree with sufficient soil and enough watering just after planting
- To plant willow at the edge of water during in the period of water recession, as following water level going down

Based on the finding, recommendations for the further works are thereby made:
- to protect middle/upper riverbank by tie-bundle of Soda hurdle work or Soda hurdle work
- To continue monitoring for several years to grasp the process and the time from planting to make the community formation.